PLANNING REPORT NO. 26

A COMPREHENSIVE PLAN FOR THE MENOMONEE RIVER WATERSHED

volume one

INVENTORY FINDINGS AND FORECASTS

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Wisconsin Coastal Zone Management Program

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Planning Report Number 26

A COMPREHENSIVE PLAN FOR THE MENOMONEE RIVER WATERSHED

Volume One

INVENTORY FINDINGS AND FORECASTS

Prepared by the
Southeastern Wisconsin Regional Planning Commission

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October 1976

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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STATEMENT OF THE CHAIRMAN

The Southeastern Wisconsin Regional Planning Commission has, since its inception, recognized the importance of water and water-related resource problems within the rapidly urbanizing seven-county Region. The Commission, after careful consideration, concluded that such problems could best be addressed within the framework of comprehensive watershed planning programs and, therefore, agreed to undertake a series of such watershed planning programs, with the individual programs however being initiated only upon the specific request of the local units of government concerned. The resulting comprehensive watershed plans are intended to provide sound recommendations for the resolution of such problems as flooding and water pollution which require the consideration of the entire drainage areas involved, and to do so within a broad framework that considers the relationship of flooding and water pollution problems to land, as well as water, use.

Pursuant to the Commission's established policy in this respect, the Common Council of the City of Wauwatosa on July 18, 1967, formally requested the Commission to undertake a comprehensive study of the Menomonee River watershed looking to the ultimate resolution of the serious and costly flooding and water pollution problems existing within that watershed. Similar formal requests were made by the Common Council of the City of Brookfield on October 3, 1967, and by the Milwaukee County Board of Supervisors on October 17, 1967. In response to these requests, the Commission on March 7, 1968, formed the Menomonee River Watershed Committee, a Committee comprised of 15 local public officials and citizen leaders drawn from throughout the watershed. The Commission initially charged that Committee with preparing a prospectus for a comprehensive study of the Menomonee River watershed, which prospectus was completed and published on November 26, 1969. Subsequently, the four county boards concerned—Milwaukee, Ozaukee, Washington, and Waukesha—approved the proposed study; and the prospectus became the basis for the conduct of the watershed planning program. As specified in the prospectus, the purpose of the program was to prepare a comprehensive plan for the physical development of the Menomonee River watershed designed not only to solve the problems of flooding, water pollution, and changing land use which exist within the watershed but to most advantageously develop the total land and water resources of that watershed and thereby provide an attractive, safe, and healthful environment for human life.

The final planning report documenting the findings and recommendations of the study consists of two volumes published simultaneously. This first volume presents a summary of the inventory findings, as well as forecasts of future growth and development within the watershed. These basic inventories and forecasts provide the basis for an in-depth analysis of the resource-related problems within the watershed, which analyses in turn provide the basis for the preparation of alternative watershed plan elements and for the selection, after public informational meetings and hearings, of the final plan from among those alternatives. The inventories also provide an invaluable bench mark of historic data upon which future studies of the watershed can be built.

In accordance with the advisory role of the Commission, this and the companion second volume are being transmitted herewith to the governmental units and agencies operating within the watershed. Consideration and careful review of this and its companion volume by all responsible public officials concerned is urged in order to provide a proper understanding not only of the inventory findings themselves, but more importantly of the definitive plans and specific recommendations for the resolution of the water resource-related problems of the Menomonee River watershed set forth in the second volume of this report.

Respectfully submitted,

George C. Berteau
Chairman

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Chapter I

INTRODUCTION

The Menomonee River watershed study is the fourth comprehensive watershed planning program to be carried out by the Southeastern Wisconsin Regional Planning Commission. Since this watershed study is an integral part of the overall work program of the Commission, an understanding of the need for, and objectives of, regional planning and the manner in which these needs and objectives are being met in southeastern Wisconsin is necessary to a proper appreciation of the Menomonee River watershed study and its findings and recommendations.

NEED FOR REGIONAL PLANNING

Regional planning is herein defined as comprehensive planning for a geographic area larger than a county but smaller than a state, united by economic interests, geography, or common areawide development problems. The need for such planning has been brought about by certain important social and economic changes which, while national phenomena, have far-reaching impacts on the problems facing local government. These changes include rapid population growth and urbanization; increasing agricultural and industrial productivity, income levels, and leisure time; generation of mass recreational needs and pursuits; increasingly intensive use and consumption of natural resources; development of private water supply and sewage disposal systems; development of extensive electric power and communications networks; and development of limited-access highway systems and mass automotive transportation.

Under the impact of these changes, entire regions, such as southeastern Wisconsin, are becoming mixed rural-urban areas. This, in turn, is creating new and intensified areawide development problems of an unprecedented scale and complexity. Rural as well as urban people must increasingly concern themselves with these problems or face irreparable damage to their land and water resources and a decline in the overall quality of their lives.

The areawide problems which necessitate a regional planning effort in southeastern Wisconsin all have their source in the rapid population growth and urbanization occurring within the Region. These areawide problems include, among others, inadequate drainage and mounting flood damages, underdeveloped sewerage and inadequate sewage disposal facilities, impairment of water supply, increasing water pollution, deterioration and destruction of the natural resource base, rapidly increasing demand for outdoor recreation and for park and open-space reservation, inadequate transportation facilities, and, underlying all of the foregoing problems, rapidly changing and unplanned land use development. These problems are all truly regional in scope, since they transcend the boundaries of any one municipality and can only be resolved within the context of a comprehensive regional planning effort involving, on a cooperative basis, all levels of government concerned.

THE REGIONAL PLANNING COMMISSION

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) represents an attempt to provide the necessary areawide planning services for one of the large urbanizing regions of the nation. The Commission was created in August 1960, under the provisions of Section 66.945 of the Wisconsin Statutes, to serve and assist the local, state, and federal units of government in planning for the orderly and economical development of southeastern Wisconsin. The role of the Commission is entirely advisory, and participation by local units of government in the work of the Commission is on a voluntary, cooperative basis. The Commission itself is composed of 21 citizen members, three from each county within the Region, who serve without pay.

The powers, duties, and functions of the Commission and the qualifications of the Commissioners are carefully set forth in the state enabling legislation. The Commission is authorized to employ experts and a staff as necessary for the execution of its responsibilities. Basic funds necessary to support Commission operations are provided by the member counties, the budget being apportioned among the several counties on the basis of relative equalized valuation. The Commission is authorized to request and accept aid in any form from all levels and agencies of government for the purpose of accomplishing its objectives, and is authorized to deal directly with the state and federal governments for this purpose. The organizational structure of the Commission and its relationship to the constituent units and agencies of government comprising or operating within the Region is shown in Figure 1.

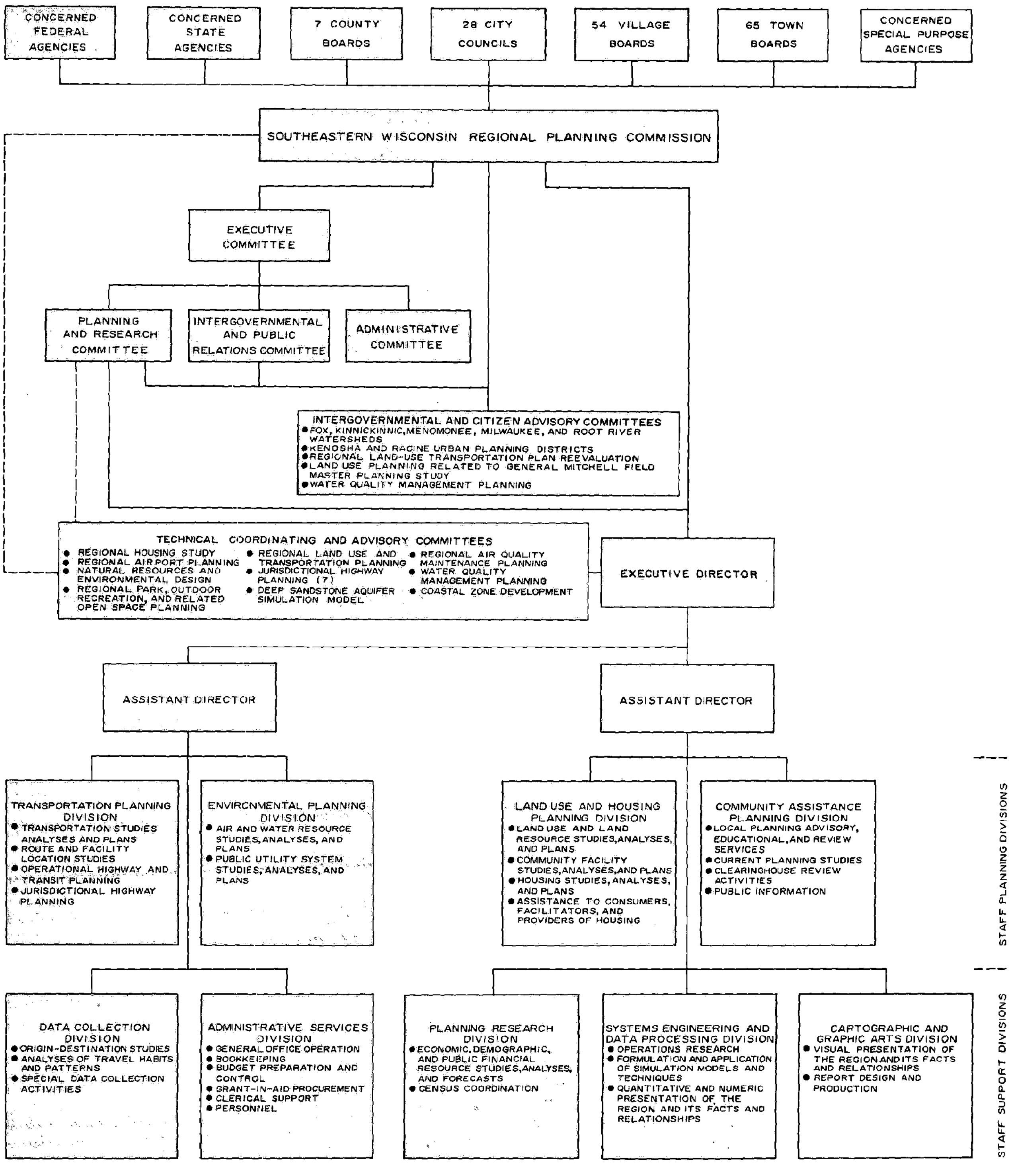
THE REGIONAL PLANNING CONCEPT IN SOUTHEASTERN WISCONSIN

Regional planning as conceived by the Commission is not a substitute for, but a supplement to, local, state, and federal planning efforts. Its objective is to aid the various levels and units of government in finding solutions to areawide developmental and environmental problems which cannot be properly resolved within the framework of a single municipality or a single county. As such, regional planning has three principal functions:

1. Inventory—the collection, analysis, and dissemination of basic planning and engineering data on a uniform, areawide basis so that, in light of such data, the various levels and agencies of govern-

Figure 1

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION: ORGANIZATIONAL STRUCTURE



Source: SEWRPC.

ment and private investors operating within the Region can better make decisions concerning community developments.

2. Plan Design—the preparation of a framework of long-range plans for the physical development of the Region, these plans being limited to those functional elements having areawide significance. To this end, the Commission is charged by law with the function and duty of "making and adopting a master plan for the physical development of the Region." The permissible scope and content of this plan, as outlined in the enabling legislation, extend to all phases of regional development, implicitly emphasizing, however, the preparation of alternative spatial designs for the use of land and for the supporting transportation and utility facilities.

3. Plan Implementation—promotion of plan implementation through the provision of a center for the coordination of the many planning and plan implementation activities carried on by the various levels and agencies of government operating within the Region.

The work of the Commission, therefore, is visualized as a continuing planning process, providing outputs of value to the making of development decisions by public and private agencies and to the preparation of plans and plan implementation programs at the local, state, and federal levels of government. The work of the Commission emphasizes close cooperation between the government agencies and private enterprise responsible for the development and maintenance of land uses within the Region and for the design, construction, operation, and maintenance of their supporting public works facilities. All of the Commission work programs are intended to be carried out within the context of a continuing planning program which provides for the periodic reevaluation of the plans produced, as well as for the extension of planning information and advice necessary to convert the plans into action programs at the local, regional, state, and federal levels.

THE REGION

The Southeastern Wisconsin Planning Region, as shown on Map 1, is comprised of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha Counties in southeastern Wisconsin. Exclusive of Lake Michigan, these seven counties have a total area of 2,689 square miles, and together comprise about 5 percent of the total area of the State of Wisconsin. About 40 percent of the state population, however, resides within these seven counties, which contain three of the eight and one-half standard metropolitan statistical areas in the state. The Region contains approximately one-half of all the tangible wealth in the State of Wisconsin as measured by equalized valuation, and represents the greatest wealth-producing area of the state, with about 42 percent of the state labor force employed within the Region. It contributes about twice as much in state taxes as it receives in state aids. The seven-county Region contains 154 local units of government, exclusive of school and other special-purpose districts, and encompasses all or parts of 11 natural watersheds. The Region has been subject to rapid population growth and urbanization, and in the decade from 1960 to 1970, accounted for 40 percent of the total population increase of the entire state.

Geographically the Region is located in a relatively good position with regard to continued growth and development. It is bounded on the east by Lake Michigan, which provides an ample supply of fresh water for both domestic and industrial use, as well as being an integral part of the major international transportation network. It is bounded on the south by the rapidly expanding northeastern Illinois metropolitan Region and on the west and north by the fertile agricultural lands and desirable recreational areas of the rest of the State of Wisconsin. Many of the most important industrial areas and heaviest population concentrations in the Midwest lie within a 250-mile radius of the Region, and over 35 million people reside within this radius, an increase of nearly 5 million persons over the 1960 level.

COMMISSION WORK PROGRAMS

Initial Work Program

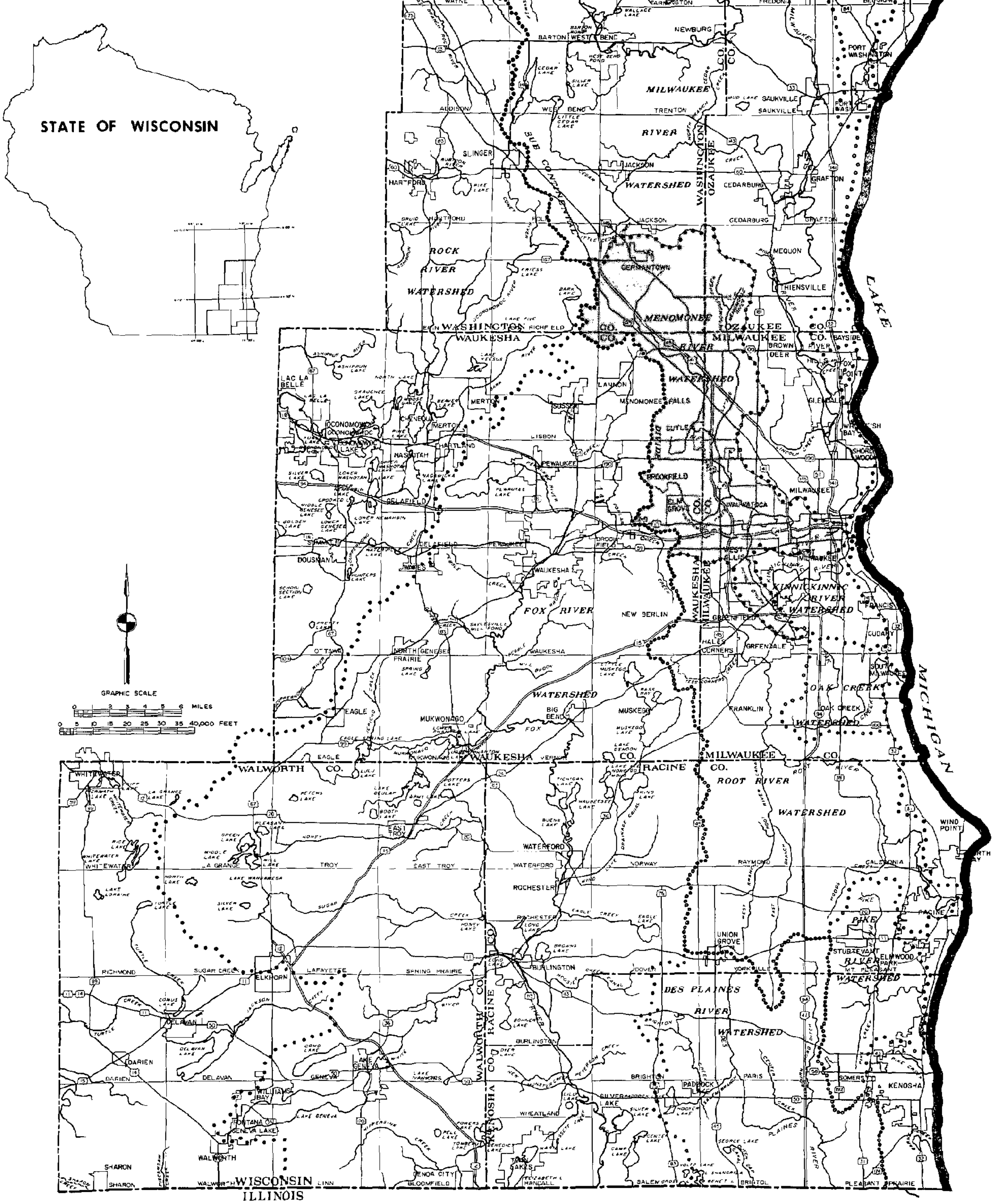
The intial work program of the Commission was directed entirely toward basic data collection. It included six basic regional planning studies, which were initiated in July 1961 and completed by July 1963: a statistical program and data processing study, a base mapping program, an economic base and structure study, a population study, a natural resources inventory, and a public utilities study.

All of these initial studies were directed toward providing a basic foundation of planning and engineering data for regional planning, and were documented in six published planning reports. None of these studies involved the preparation of plans. Their findings, however, provided a valuable point of departure for all subsequent Commission work, including the Menomonee River watershed planning program.

Also as part of its initial work program, the Commission adopted a policy of community planning assistance wherein functional guidance and advice on planning problems are extended to local units of government and through which regional planning studies are interpreted locally and regional plans may be integrated with local plans. Six local planning guides have been prepared to date under this community assistance program to provide municipalities throughout the Region with information helpful in the preparation of sound local planning and plan implementation codes and ordinances. These guides will aid in implementing both regional and local plans, and will further assist local public officials in carrying out their day-to-day planning functions. The subjects of these guides are land development, official mapping, zoning, organization of local planning agencies, floodland and shoreland development, and use of soil survey data in

Map 1

LOCATION OF THE
MENOMONEE RIVER WATERSHED
IN THE SOUTHEASTERN
WISCONSIN REGION



The Menomonee River watershed is an integral part of the rapidly urbanizing seven-county Southeastern Wisconsin Region. This Region, while comprising only 5 percent of the total area of the state, contains over 40 percent of the state's population, provides employment for almost one-half of the state's labor force, and contains approximately one-half of all the tangible wealth of the state. The Menomonee River watershed is the fifth largest of the eleven major watersheds located wholly or partly in the Region. About 20 percent of the 1970 population of the Region resided within this extensively urbanized watershed, which comprises only about 5 percent of the area of the Region.

Source: SEWRPC.

planning and development. All include model ordinances, and all provide a framework for plan implementation through local land use control measures.

Land Use-Transportation Study

The first major work program of the Commission actually directed toward the preparation of long-range development plans was a regional land use-transportation study, initiated in January 1963 and completed in December 1966. This program produced two key elements of a comprehensive plan for the physical development of the Region: a land use plan and a transportation (highway and transit) plan. The findings and recommendations of the regional land use-transportation study, which has provided many important contributions to the comprehensive watershed planning programs of the Commission, have been published in the three-volume SEWRPC Planning Report No. 7, Regional Land Use-Transportation Study; in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin; and five supporting technical reports, including SEWRPC Technical Report No. 4, Water Quality and Flow of Streams in Southeastern Wisconsin.

Root River Watershed Study

The Root River watershed study was the first comprehensive watershed planning program, and the second major work program actually directed toward the preparation of long-range development plans, undertaken by the Commission. This study was initiated in July 1964 and completed in July 1966. The findings and recommendations were published in SEWRPC Planning Report No. 9, A Comprehensive Plan for the Root River Watershed, and in supporting SEWRPC Technical Report No. 2, Water Law in Southeastern Wisconsin. The comprehensive watershed plan documented in these reports contains specific recommendations for the abatement of the flooding, water quality, and related land use and natural resource conservation problems of this 197 square mile watershed.

The Commission adopted the comprehensive plan for the Root River watershed on September 22, 1966. As of January 1, 1975, the recommended plan had been formally adopted by the Milwaukee and Racine County Boards of Supervisors; by the Metropolitan Sewerage Commission of the County of Milwaukee and the Sewerage Commission of the City of Milwaukee; by the Common Councils of the Cities of Franklin, Oak Creek, and Racine; and by the Town Board of the Town of Mt. Pleasant.

On February 5, 1971, the Root River watershed plan was certified by the Wisconsin Department of Natural Resources to the U. S. Environmental Protection Agency as the state-approved water quality management plan for the Root River basin, and on September 14, 1971, the U. S. Environmental Protection Agency approved the Root River watershed plan. Thus, the Root River watershed plan currently stands as an approved basin plan which is being utilized by the state and federal agencies in support of the review and award of federal grants-in-aid for sewerage and water quality control facility construction. Substantial progress has been made toward implementation of this plan as documented in the Commission series of annual reports.

Fox River Watershed Study

The Fox River watershed study was the second comprehensive watershed planning program and the third major work program directed toward the preparation of long-range development plans to be undertaken by the Commission. This study was initiated in November, 1965 and completed in February 1970. The findings and recommendations were published in SEWRPC Planning Report No. 12, A Comprehensive Plan for the Fox River Watershed, Volume 1, Inventory Findings and Forecasts, and Volume 2, Alternative Plans and Recommended Plan. The comprehensive watershed plan documented in this report contains recommendations for the abatement of the flooding, water quality, water supply, recreation, and related land use and natural resource conservation problems of this watershed. The study also produced special lake use reports for selected major lakes of the watershed.

The Fox River watershed study differed from the Root River study in that it was not conducted for an entire watershed, but only for the headwater portion of the Fox River basin. The attention of the Commission was focused primarily on the 942 square miles of the watershed lying in Wisconsin, but the Commission recognized the relationship of this headwater area to the 1,640 square mile portion of the Fox River watershed located in Illinois.

The Commission adopted the comprehensive plan for the Fox River watershed on June 4, 1970. As of January 1, 1975, the Fox River watershed plan had been formally adopted by the Kenosha, Milwaukee, Racine, Walworth and Waukesha County Boards of Supervisors; by the Common Councils of the Cities of Brookfield, Burlington, New Berlin, and Waukesha; by the Village Boards of the Villages of Rochester, Silver Lake, Menomonee Falls, Pewaukee, and Sussex; by the Town Boards of the Towns of Brookfield, Lisbon, Pewaukee, and Waterford; by the Kenosha County Soil and Water Conservation District; and by the Lake Pewaukee Sanitary District. The plan has also been formally endorsed or acknowledged by the U. S. Department of Housing and Urban Development; the U. S. Department of Agriculture, Soil Conservation Service; the U. S. Department of the Interior, Geological Survey; the U. S. Department of Transportation, Federal Highway Administration; and the Wisconsin Department of Transportation.

On June 11, 1971, the Wisconsin Natural Resources Board approved the comprehensive Fox River watershed plan, and on July 21, 1971, certified the plan to the U. S. Environmental Protection Agency as the interim basin plan for the Fox River basin in Wisconsin. In reviewing the plan, the Environmental Protection Agency indicated that before formal federal approval would be forthcoming, two issues relating to the timetable for plan implementation should be addressed, one dealing with the nutrient removal requirements in the plan and the other with implementation of the proposed areawide sewerage system in the upper watershed.

In response to this request by the Environmental Protection Agency, the Wisconsin Department of Natural Resources, the Regional Planning Commission, and the local units of government concerned cooperatively prepared a specific plan implementation schedule that included timely phosphorus removal recommendations for the entire watershed and a recommendation that the plan be amended to include two major sewage treatment plants for the upper watershed area. On September 13, 1973, the Commission took formal action to amend the Fox River watershed plan to include the two-sewage-treatment-plant alternative in lieu of the one-sewage-treatment-plant alternative for the upper watershed area in the adopted plan, and to further include as part of the adopted plan the Revised Implementation Schedule for Meeting Water Quality Objectives and Waste Treatment Requirements for the Fox-Illinois River Watershed, published in August 1973 by the Wisconsin Department of Natural Resources. On January 9, 1974, the Wisconsin Natural Resources Board certified the plan amendment to the Environmental Protection Agency, and on April 5, 1974, that agency gave full approval to the Fox River comprehensive plan as the water quality management plan for the Fox River basin. Progress toward implementation of the amended plan is documented in the Commission series of annual reports.

Milwaukee River Watershed Study

The Milwaukee River watershed study was the third comprehensive watershed planning program undertaken by the Commission, and the fourth major work program directed toward the preparation of long-range physical development plans. The study was initiated in October 1967 and was completed in October 1971. The findings and recommendations were published in SEWRPC Planning Report No. 13, A Comprehensive Plan for the Milwaukee River Watershed, Volume 1, Inventory Findings and Forecasts, and Volume 2, Alternative Plans and Recommended Plan. Like the plan for the Fox River watershed, the plan for the Milwaukee River watershed contains recommendations for the abatement of the flooding, water quality, water supply, recreation, and related land and natural resource conservation problems of this important watershed. The study also produced special lake use reports for selected major lakes of the watershed. Of particular importance to the Menomonee River watershed study are the recommendations for the abatement of water pollution from combined sewer overflows produced by the Milwaukee River watershed study. These recommendations extend to all of the combined sewer service areas in Milwaukee, including such areas within the Menomonee River watershed.

The Milwaukee River watershed study differed from the Root and Fox River watershed in that a significant portion—about 38 percent—of the headwater area of the 694 square mile watershed is located outside and north of the seven-county Region. It was evident from the beginning that the entire watershed should be included in any comprehensive planning program. This meant including in the study the considerable portions of the watershed lying outside of the Region in Fond du Lac and Sheboygan Counties, as well as the very small area of the watershed lying in Dodge County. Fond du Lac and Sheboygan Counties were accordingly requested to join in the work of the Watershed Committee, and their consent and participation marked the first time that neighboring counties formally and actively participated in Commission planning programs.

The comprehensive Milwaukee River watershed plan was formally adopted by the Commission in March 1972. As of January 1, 1975 the plan had been formally adopted by the Milwaukee, Ozaukee, Sheboygan, and Washington County Boards of Supervisors; by the Common Council of the City of Milwaukee; by the Village Boards of the Villages of River Hills and Saukville; by the Town Board of the Town of Fredonia; by the Sewerage Commission of the City of Milwaukee and the Metropolitan Sewerage Commission of the County of Milwaukee; by the City of Milwaukee Board of Harbor Commissioners; and by the Milwaukee County Park Commission. The watershed plan has also been formally endorsed or acknowledged by such important state and federal agencies as the Wisconsin Board of Soil and Water Conservation Districts; the Wisconsin Board of Health and Social Services; the Wisconsin Department of Transportation; the U. S. Department of Agriculture, Soil Conservation Service and Farmers Home Administration; the U. S. Department of Housing and Urban Development; the U. S. Department of the Interior, Geological Survey and Bureau of Outdoor Recreation; and the U. S. Department of Transportation, Federal Highway Administration.

The Wisconsin Natural Resources Board on July 26, 1972, approved the Milwaukee River watershed plan, and on August 3, 1972, certified the plan to the U. S. Environmental Protection Agency as the approved water quality management plan for the basin. On March 19, 1973, the latter agency approved the plan, noting that the plan "....is certainly without equal in the State of Wisconsin with respect to comprehensiveness and quality of planning."[1] Thus, the Milwaukee River watershed plan currently stands as an approved basin plan which is being utilized by the state and federal agencies in support of the review and award of federal grants-in-aid for sewerage and water quality control facility construction.

Regional Sanitary Sewerage System Planning Program

The Commission initiated a regional sanitary sewerage system planning program in July 1969 as a result of a Commission determination that the preparation of a regional sanitary sewerage system plan would be the logical next step in the preparation of a comprehensive plan for the physical development of the Region. This planning program was designed to provide a long-range plan for the resolution of problems associated with the need for new sanitary sewer service within the Region; with the need to improve existing inadequate sanitary sewer service, particularly in newly developed areas of the

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[1] *Letter from Francis T. Mayo, Regional Administrator, U. S. Environmental Protection Agency, to L. P. Voight, Secretary, Wisconsin Department of Natural Resources, dated March 19, 1973.*

Region; with serious surface water quality pollution, together with increasing conflicts over water uses and demand for water pollution abatement; with the widespread occurrence within the Region of soils unsuited to the use of onsite septic tank sewage disposal systems; and with the development of small, isolated sewage treatment plants on an uncoordinated basis. The program was intended to aid and assist in implementation of the adopted regional land use plan, as well as to fulfill the Commission's responsibilities to its constituent units of government to prepare an areawide sanitary sewerage system plan in order to maintain the eligibility of local units of government in the Region to qualify for federal grants in partial support of the construction of sanitary sewerage facilities.

The sanitary sewerage system plan, which was completed in 1974, is very closely related to completed comprehensive watershed plans, since it provides an important means for relating the water pollution abatement actions recommended in the individual watershed plans to each other and to development within the Region as a whole. The regional sanitary sewerage system planning program, while related to the protection of water resources, is more directly concerned with the broader, more pervasive need to promote orderly areawide land use development, and thereby offers a logical means for more fully integrating the individual watershed plans and for refining and adjusting these plans as necessary.

The sanitary sewerage system plan affects the Menomonee River watershed study inasmuch as it includes recommendations for intercepting all sanitary sewage from all municipal sanitary sewer systems within the watershed for conveyance to the sewage treatment plants operated by the Sewerage Commission of the City of Milwaukee. Thus, water quality inventory analyses and plan synthesis under the Menomonee River watershed study will, because of the regional sanitary sewerage system planning program, be able to devote minimal attention to municipal wastewater treatment problems, and instead concentrate on the resolution of water pollution problems attributable to urban storm water runoff, agricultural runoff, and industrial-commercial discharges within the watershed.

Other Regional and Subregional Planning Programs

Four additional regional planning programs have been undertaken by the Commission. A regional library system planning program was completed in 1974, and a regional airport system planning program, a regional housing study, and a regional park, outdoor recreation, and related open space study are underway. The Commission has also completed more detailed urban development plans for certain subareas of the Region, including the Kenosha and Racine Planning Districts.

THE MENOMONEE RIVER WATERSHED STUDY

The Menomonee River watershed study is the fourth comprehensive watershed planning program to be undertaken by the Commission. It is, however, the first such study to be conducted by the Commission for a watershed which is extensively urbanized and which is expected to become almost entirely urbanized in the near future. Although the 137 square mile watershed encompasses only 5 percent of the Planning Region area, 348,000 people, or about 20 percent of the population of southeastern Wisconsin, reside within the watershed.

Initiation of the Menomonee River Watershed Study

The Menomonee River watershed study was initiated upon the specific request of local units of government within the watershed as a result of growing concern by local public officials and citizen leaders over increasing problems of flooding, water pollution, park and open space needs, industrial water supply, and changing land use. All of these problems interact to adversely affect the quality of urban life and to cause further deterioration and destruction of the natural resource base of the watershed.

Concern over what at first seemed to be local problems within subareas of the watershed was followed by a growing awareness among public officials that the causes and effects of these problems transcend local municipal boundaries, and are related to the entire stream network and tributary drainage areas. Recognizing the Commission as the logical and best equipped agency to find practical and permanent solutions to these problems, the Common Council of the City of Wauwatosa on July 18, 1967, formally requested the Commission to undertake a comprehensive planning study of the Menomonee River watershed, looking to the ultimate resolution of the aforementioned water resource and water resource-related problems within the context of a long-range comprehensive watershed planning effort. On October 3, 1967, and on October 17, 1967, similar requests were made by the Common Council of the City of Brookfield and the Board of Supervisors of Milwaukee County.

The Commission accordingly on March 7, 1968, formed the Menomonee River Watershed Committee, comprised of knowledgeable state and local public officials and citizen leaders from throughout the watershed. This Committee was created to assist the Commission in its study of the problems of the Menomonee River watershed, and the Committee began at once to prepare a Prospectus for the necessary comprehensive watershed planning program. The full membership of the Menomonee River Watershed Committee is listed in Appendix A.

The Committee identified and described in the Prospectus five basic problems within the watershed that required careful areawide study for sound resolution. These problems include flooding, water pollution, park and open space reservation, industrial water supply, and changing land use. These problems are inextricably interrelated, and this fact precludes their study and sound resolution on an individual basis.

The Prospectus prepared by this Committee was endorsed by the Commission in November 1969; published; and in accordance with the advisory role of the Commission, transmitted to the governmental agencies concerned for their consideration and action. All four county boards concerned—Milwaukee, Ozaukee, Washington, and Waukesha—as well as the Wisconsin Department of Natural Resources formally endorsed the Prospectus and agreed to provide the state and local funds necessary for execution of the indicated planning program. The U. S. Department of Housing and Urban Development and the U. S. Environmental Protection Agency (formerly the U. S. Department of the Interior, Federal Water Pollution Control Administration) also endorsed the Prospectus, and agreed to provide the federal funds necessary for execution of the program. All the necessary commitments from these local, state and federal agencies were not received until early 1972.

In order to accomplish the financing of the study as outlined in the Prospectus, it was necessary for the Commission to effect separate contractual agreements with the U. S. Department of Housing and Urban Development; the U. S. Environmental Protection Agency; the Wisconsin Department of Natural Resources; and the four counties containing portions of the watershed. Under the contracts between the federal and state agencies and the Commission, the Commission agreed to complete the necessary planning work in accordance with the Prospectus; and the Wisconsin Department of Natural Resources, the U. S. Department of Housing and Urban Development, and the U. S. Environmental Protection Agency agreed to provide funds in partial support of the planning program under state legislation, under Section 701 of the Federal Housing Act of 1954 as amended, and under Title 3 of the Federal Water Resources Act of 1965 as amended.

Under the contracts between the four counties concerned and the Commission, the latter agreed to complete the necessary planning work and the former agreed to provide the local funds necessary to support the work. Pursuant to the state regional planning enabling act, the local study costs, amounting to 12.0 percent of the total Menomonee River watershed study costs, were allocated to the respective counties on the basis of each county's proportionate share of the state equalized assessed valuation of the watershed. The percentage share of the total study costs of $232,900 agreed upon in the contracts were: U. S. Department of Housing and Urban Development, 20.0 percent; U. S. Environmental Protection Agency, 35.0 percent; Wisconsin Department of Natural Resources, 33.0 percent; Milwaukee County, 10.3 percent; Ozaukee County, 0.1 percent; Washington County, 0.1 percent; and Waukesha County, 1.5 percent.

The Prospectus, as prepared by the Watershed Committee and published by the Commission, was not a finished study design. It was a preliminary design prepared to obtain support and financing for the necessary study, an objective which was fully achieved. Major work elements, a staff organization, a time schedule, and cost estimates were set forth in the Prospectus. Work on the study, as outlined in the Prospectus, began in March 1972.

Study Objectives

The primary objective of the Menomonee River watershed planning program, as set forth in the Prospectus, is to assist in abating the serious water resource and water resource-related problems of the Menomonee River basin by developing a workable plan to guide the staged development of multipurpose water resource facilities and related resource conservation and management programs for the watershed. This plan, to be effective, must be amenable to cooperative adoption and joint implementation by all levels and agencies of government concerned. It must be capable of functioning as a practical guide for the making of decisions concerning both land and water resource development within the watershed so that, through such implementation, the major water resource and water resource-related problems within the watershed may be abated and the full development potential of the watershed realized. More specifically, the objectives of the planning program are to:

1. Prepare a plan for the management of floodlands along the major waterways of the Menomonee River watershed, including measures for the mitigation of existing flood problems and also incorporating elements intended to minimize future flood problems.

2. Prepare a plan for surface and ground water quality management for the Menomonee River watershed, incorporating measures to abate existing pollution problems and including elements intended to prevent future pollution problems.

3. Prepare a plan for public open space reservation and for recreational development, including measures for the preservation and enhancement of the remaining woodlands, wetlands, and fish and wildlife habitat of the watershed.

4. Prepare a plan for industrial water supply, properly relating anticipated water needs to the quantity and quality of both groundwater and surface water supplies.

5. Refine and adjust the regional land use plan to reflect the conveyance, storage, and waste assimilation capabilities of the perennial waterways and floodlands of the watershed; to include feasible water control facilities; and generally to promote the rational adjustment of land uses in this urbanizing basin to the surface and ground water resources.

Special Consideration with Respect to the Lake Michigan Estuary

As shown on Map 1, the watershed contains portions of Milwaukee, Ozaukee, Washington, and Waukesha Counties. Some of the most intensely urbanized portions of the Region lie within this relatively small watershed. Although the entire Menomonee River watershed, from its rural headwater area in Washington County to its confluence with the Milwaukee River near the Lake Michigan shoreline, was included in the comprehensive watershed planning program with respect to the flood control and floodland management plan elements of the study, primary attention with respect to the other elements of the study—water pollution, park and open space needs, industrial water supply, and changing land use—was focused on that part of the watershed lying upstream of the low head dam located at 29th Street extended in the City of Milwaukee. That 2.2 mile reach of the Menomonee River lying below the low head dam, in combination with the Milwaukee River below the North Avenue Dam and the Kinnickinnic River downstream of Chase Avenue, forms an estuary of Lake Michigan as shown on Map 2.

It is the Commission position that, with the exception of floodland management, the "harbor" estuary should be studied separately from the tributary Milwaukee, Menomonee, and Kinnickinnic River watersheds. There is a physical reason as well as a planning reason—the latter relating to the community of interest concept discussed below—for the position of the Commission that the estuary area should be excluded from watershed studies in general and the Menomonee River watershed study in particular. From a physical standpoint, the hydraulic characteristics and behavior of the three tributary streams above the point at which they enter the estuary is distinctly different from, and considerably less complex than, the hydraulic characteristics and behavior of the estuary area. Rivers upstream of the estuary are in essentially continuous, downstream flow, and except for extremely high lake levels which must be accounted for in watershed studies, are unaffected by Lake Michigan water levels. In contrast, the estuary portion of each of the three rivers exhibits flow reversals, stage fluctuations, thermal stratification and related currents, and periods of relative calm, all of which are attributable to the hydraulic connection between the estuary and Lake Michigan.

The complete resolution of water quality problems in any portion of the estuary—for example, the Menomonee River downstream of 29th Street—must ultimately incorporate an analysis of the entire estuary. The completed comprehensive plan for the Milwaukee River watershed, plus the inventory, analyses, and recommendations included in and emanating from the Menomonee River watershed study, will contribute to the ultimate resolution of estuary problems. These two watershed studies provide information on flow contributions to the estuary, and include recommendations with respect to the elimination of pollution sources lying entirely outside of the estuary area and one source—combined sewers—shared by both the estuary and the Milwaukee, Menomonee, and Kinnickinnic River watersheds. The ultimate solution of estuary problems, one of which is water pollution, must, however, await a detailed planning study of the estuary because of the hydraulic interdependence of the estuary components and Lake Michigan.

The Commission believes that the delineation of watersheds as planning areas must recognize not only the physical features—for example, topographic divides and hydraulic interconnections—influencing a technically sound watershed planning operation, but also the existence of a significant community of interest upon which the active participation of local officials and citizen leaders in the planning effort can be obtained. Although the Menomonee, Milwaukee, and Kinnickinnic Rivers physically join in the estuary at the Lake Michigan shoreline, the promotion of a single community of interest throughout all three of these river basins would be most difficult. Residents of the Milwaukee and Kinnickinnic River basins have little in common with respect to land and water resource problems with residents of the Menomonee River basin. The strong community of interest is, however, shared by those private and public segments of the Milwaukee metropolitan area population having some involvement in any aspect of the estuary and immediate lakeshore area.

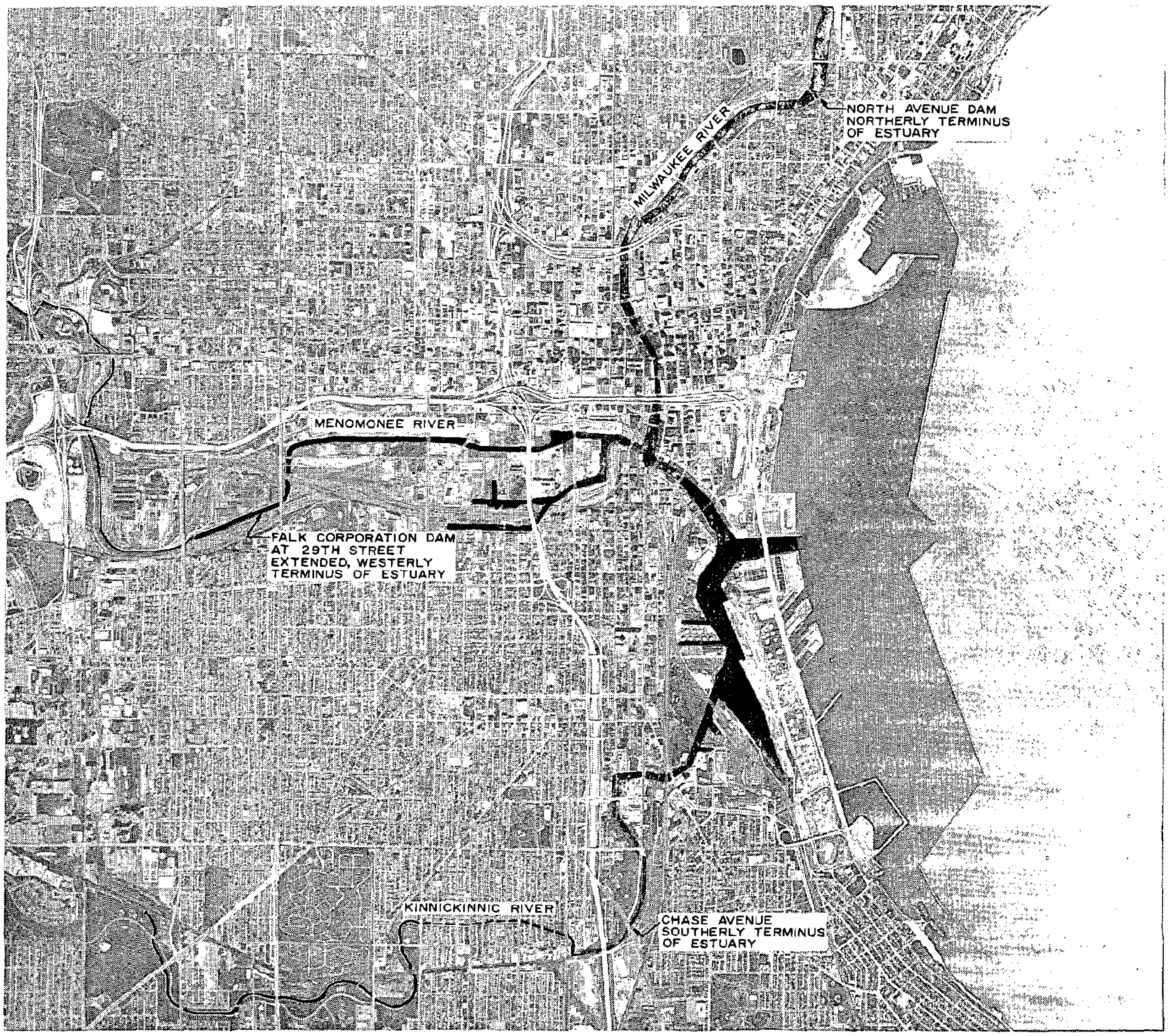
Commercial Great Lakes shipping and interconnections between that shipping and land, rail, and truck transportation may be expected to be of common concern to the estuary area business community. This commercial activity is bound to conflict with, and be affected by, existing and potential recreational uses of the estuary area as well as the nearby beaches. For example, the increased popularity of Lake Michigan pleasure boating and sportfishing will increase the need for marinas and other related services, with the impact of these pressures being shared by most of the estuary community. As part of an effort to improve upon retail activity and the provision of services in the Milwaukee business district, business leaders may be expected to become increasingly interested in the protection and even restoration of the rivers and the Lake Michigan shoreline in, and near the central urban area. Such efforts by the estuary-harbor community could provide for additional park and open space areas and would, at least indirectly, reflect on the success of retail and service activities.

Thus, while a portion of the estuary area would, under a strict topographic divide definition, be included in the Menomonee River watershed, it has been excluded from the watershed study because that 2.2 mile reach of the river hydraulically functions as an estuary of Lake Michigan, and equally important, because that portion of the Menomonee River shares a community of interest with the estuary and immediate lakeshore areas that is markedly stronger than its ties with those portions of the Menomonee River watershed lying above the estuary.

The watershed study will, accordingly, incorporate only those aspects of the estuary that have direct bearing on the watershed above the estuary. Examples include the necessity of determining the effect of Lake Michigan levels on Menomonee River flood stages above the low head dam at 29th Street, and the need to include the estuary and lakeshore area in possible refinements to the combined sewer overflow recommendations which were originally set forth in the comprehensive plan for the Milwaukee River watershed.

Map 2

THE LAKE MICHIGAN ESTUARY AS FORMED BY THE CONFLUENCE
OF THE MENOMONEE, MILWAUKEE, AND KINNICKINNIC RIVERS



The Menomonee, Milwaukee, and Kinnickinnic Rivers all join in the Lake Michigan estuary and harbor within the City of Milwaukee before discharging to Lake Michigan. The westerly terminus of the estuary is located 2.2 miles up the Menomonee River at a low head dam located west of the 27th Street Viaduct in the City of Milwaukee. With the exception of incorporating certain upstream hydraulic effects directly attributable to high lake levels, it is the Commission's position that the estuary should be studied separately from the three tributary watersheds after comprehensive plans are completed for those watersheds, since the estuary has common physical characteristics that differ from those of the tributary watersheds, and also constitutes a single community of interest with respect to business, commercial, industrial, and recreational activities.

Source: SEWRPC.

Other Major Studies and Their Relationship to the Menomonee River Watershed Planning Program

During the course of the Menomonee River watershed planning program, two major research and demonstration projects were initiated in the watershed. Inasmuch as the early stages of these two projects were coincident with the Menomonee River watershed planning program, questions may be raised as to the objectives and content of these two projects, particularly as they relate to the planning program. The following discussion of the two research and demonstration projects describes the objectives of each, the rationale for selecting the Menomonee River watershed, and the relationship between each of the two projects, and the SEWRPC Menomonee River watershed planning program.

The Menomonee River Pilot Watershed Study: On April 15, 1972, the governments of Canada and the United States signed the Great Lakes Water Quality Agreement and requested that the International Joint Commission (IJC)[2] investigate pollution of the Great Lakes from various land use activities. Subsequent to the signing of the Great Lakes Water Quality Agreement, the IJC established the Great Lakes Water Quality Board, and assigned to it the responsibility for carrying out the provisions of the Agreement. The Water Quality Board created the International Reference Group on Great Lakes Pollution from Land Use Activities for the purpose of carrying out studies related to the effect of land use on Great Lakes water quality.

Included in the work plan[3] of the Reference Group are a series of intensive pilot studies of a small number of watersheds within the Great Lakes basin. These watersheds were carefully selected to permit extrapolation of the data and findings of the pilot studies to the entire Great Lakes basin, and to relate water quality degradation found at river mouths to specific land uses in the tributary areas. A total of seven watersheds—three in Canada and four in the U. S.—were selected by the Reference Group to be the subject of these pilot studies.

The Menomonee River watershed was selected as one of the seven watersheds to be studied, with emphasis upon the impact of urban land uses on Great Lakes water quality. Two factors entered into the selection by the Reference Group of the Menomonee River watershed for such an intensive study. First, the watershed is not only highly urbanized, but it contains a wide variety of urban land uses, including low, medium, and high density residential, commercial, and industrial land uses. Second, the Reference Group was aware that the Southeastern Wisconsin Regional Planning Commission was, in late 1973 at the time of selection of the watersheds, preparing a comprehensive plan for the watershed. Information obtained or developed during the inventory, analysis, and forecast phases of this Commission planning effort, as well as information obtained under other Commisison land and water resource planning programs, would be available to and would provide a substantial data and information base for the IJC study.

Preliminary work on the Menomonee River Pilot Watershed Study was initiated in 1973, the project was funded by the U. S. Environmental Protection Agency on May 10, 1974, and the project is scheduled for completion in early 1978. The principal objectives of the Menomonee River Pilot Watershed Study are:

1. To determine the levels and quantities of major and trace pollutants, including but not limited to nutrients, pesticides, and sediments reaching and moving in stream systems tributary to the Great Lakes.

2. To identify the sources and evaluate the behavior of pollutants from an urban complex, with particular emphasis on the potential impact of residential, commercial, and industrial land use development, including supporting utility and transportation facilities, and of construction activities associated with rapid urbanization, on stream water quality.

3. To develop the predictive capability necessary to facilitate extension of the findings of the Menomonee River Pilot Watershed Study to other urban settings, leading to an eventual goal of permitting pollution inputs from urban sources to be accurately estimated for the entire Great Lakes Basin.

As is evident from these objectives, the Menomonee River Pilot Watershed Study is primarily a research endeavor, with emphasis on the effect of land use on Great Lakes water quality. This contrasts markedly with the SEWRPC Menomonee River watershed planning program, which is a comprehensive planning effort intended to lead to

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[2] *The IJC, established in 1912 under provisions of the 1909 Canada-U. S. Boundary Waters Treaty, is comprised of six members, including three Canadian and three U. S. representatives. The IJC has two major responsibilities. The first is to approve or reject all proposals involving the utilization, obstruction, or diversion of surface waters on either side of the Canada-U. S. boundary. IJC actions with respect to proposals are final. The second is to investigate and make recommendations concerning special projects and problems in response to requests—formally referred to as references—received from either or both governments. IJC actions with respect to references, which have dealt with a variety of topics including air and water pollution, are not binding on either of the two governments. For a detailed discussion of the IJC, refer to: "A Proposal for Improving the Management of the Great Lakes of the United States and Canada," Technical Report No. 62, Water Resources and Marine Sciences Center, Ithaca, New York, January, 1973.*

[3] *"Detailed Study Plan to Assess Great Lakes Pollution from Land Use Activities," submitted to the Great Lakes Water Quality Board, International Joint Commission, by the International Reference Group on Pollution of the Great Lakes from Land Use Activities, March 1974, 128 pp.*

specific recommendations for the solution of existing water resource problems within the watershed and the prevention of future problems. Although the research study and the planning study complement each other in that they share a common data base, the two studies differ markedly in content, methodology, and objectives.

The Wisconsin Department of Natural Resources, the University of Wisconsin System Water Resources Center, and the Southeastern Wisconsin Regional Planning Commission constitute the three lead agencies, or organizations, responsible for participating with the IJC Reference Group in the planning and conduct of the Menomonee River Pilot Watershed Study. The Regional Planning Commission will contribute to the conduct of the pilot study by performing, in cooperation with other study participants and under a subcontract to the Wisconsin Department of Natural Resources, three principal functions: project management, data provision, and systems analysis. The project management function will be carried out by SEWRPC in a joint effort with the other two lead organizations in the Menomonee River Pilot Watershed Study. This function is intended to provide overall direction to, and control of, the Menomonee River Pilot Watershed Study, culminating in the attainment of the study goals as set forth above. The second function, that of data provision, is intended to make available to the Menomonee River Pilot Watershed Study all historical and existing SEWRPC information, as well as new information obtained during the course of the SEWRPC Menomonee River watershed planning program. The third and final SEWRPC function is systems analysis, which is intended to result in the development of a digital computer data management system to facilitate the storage, retrieval, analysis, and display of all data and information applicable to the Menomonee River Pilot Watershed Study, and to lay the foundation for the development of a digital computer model having the predictive capability needed to facilitate extension of the findings from the Menomonee River watershed to other urban areas tributary to the Great Lakes.

<u>The Washington County Project:</u> The Federal Water Pollution Control Act Amendments of 1972 focused attention on certain diffuse, or, nonpoint, pollution sources, including sediments. This legislation encouraged the evaluation of the sources and extent of sediment and related pollution associated with both agricultural and urban lands. Examination of the legal, economic, and other aspects of the implementation of erosion and sediment control methodology was also called for in the legislation.

In response to the provisions of the 1972 Amendments, a demonstration project was initiated in Washington County in July 1974 under the leadership of the Wisconsin State Board of Soil and Water Conservation Districts and the University of Wisconsin System. Although more commonly known as the Washington County Project, the formal name of this demonstration study is "Development and Implementation of a Sediment Control Ordinance: Institutional Arrangements Necessary for Implementation of Control Methodology on Urban and Rural Lands."[4] The principal objectives of the Washington County Project as set forth in the funding application to the U. S. Environmental Protection Agency are:

1. Demonstrate, through a monitoring program, the effectiveness of land use control techniques in improving surface water quality.

2. Develop a model sediment control ordinance acceptable to landowners and the several governmental authorities responsible for regulatory measures in incorporated and unincorporated areas on a countywide basis.

3. Determine the combination of institutional arrangements in the form of laws, and intergovernmental relationships involving federal, state, county, and municipal governments, required for implementing the ordinance in incorporated and unincorporated areas.

4. Develop a description of the personnel required and the level of technical assistance needed to implement a sediment control program using a regulatory approach.

5. Develop and systemize the educational and informational dissemination effort required for implementing a sediment control program using a regulatory approach.

6. Predict the water quality benefits to be derived from the implementation of similar ordinances throughout the Great Lakes Drainage Basin, and develop educational materials useful for implementing sediment control programs throughout the Region.

In addition to the Wisconsin Board of Soil and Water Conservation Districts and the University of Wisconsin System, the following governmental units and agencies are cooperating in the conduct of the Washington County Project: The Wisconsin Geological and Natural History Survey; the U. S. Department of Agriculture, Soil Conservation Service; the U. S. Department of Interior, Geological Survey; the Washington County Board; the Washington County Soil and Water Conservation Supervisors; the Village of Germantown; and the Southeastern Wisconsin Regional Planning Commission.

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[4] *"Development and Implementation of a Sediment Control Ordinance: Institutional Arrangements Necessary for Implementation of Control Methodology on Urban and Rural Lands," Application to the U. S. Environmental Protection Agency from the University of Wisconsin System on behalf of the Wisconsin Board of Soil and Water Conservation Districts, February 28, 1974, 50 pp.*

The primary function of the SEWRPC in this study is the provision of data and information about the natural resource base and man-made features of Washington County. This data and information base has been assembled by the Commission as a result of its land and water resource planning efforts, including the Milwaukee and Menomonee River watershed planning programs. In addition to the primary function of data and information provision, the Commission will assist in the preparation of detailed land use plans for selected demonstration areas, serve on committees established to manage the study, and assist in implementation of the study findings. The SEWRPC is providing the above services under contract to the University of Wisconsin System. The Washington County Project was initiated in July 1974 and is scheduled for completion in June 1978.

Washington County was selected as the site for the demonstration project for a variety of reasons, including the extensive data and information base available from the SEWRPC and the existence of a variety of rural and urban subbasins within the county. Another factor entering into the selection of Washington County was the expressed interest of local communities and governmental units in solving erosion and sedimentation problems attendant to agricultural activities and urbanization. The Washington County Project will focus on field studies of two areas: an agricultural area tributary to Cedar Creek in the Milwaukee River watershed, and an urbanizing area in the Village of Germantown tributary to the Menomonee River.

The SEWRPC Menomonee River watershed planning program will complement the Washington County Project in that hydrologic, hydraulic, and water quality information developed under the Commission watershed study will be available for the study of the urbanizing areas in the Village of Germantown. The Washington County Project should complement the SEWRPC Menomonee River watershed planning program by demonstrating the effectiveness of land use control practices on surface water quality enhancement, and by developing an effective model erosion and sediment control ordinance.

Staff, Cooperating Agency, Consultant, and Committee Structure

The basic organizational structure for the study is outlined in Figure 2, and consists of the cooperating state and federal agencies, consultants, and Commission staff reporting to the Chief Environmental Planner as the interstaff project coordinator, who reports to the Executive Director, who, as a professional engineer, serves as project sponsor. The Executive Director, in turn, reports to the Southeastern Wisconsin Regional Planning Commission. The responsibilities of the cooperating federal and state agencies, consultants, and Commission staff for the conduct of major elements of the planning study are also indicated in Figure 2.

A comprehensive watershed planning program necessarily covers a broad spectrum of related governmental and private development programs, and no agency, whatever its function or authority, can operate independently in the conduct of such a study. The basic Commission organization provides for the attainment of the necessary interagency coordination through the establishment of advisory committees, as well as through interagency staff assignment. Two types of such committees are provided as an integral part of the organization for the watershed planning work.

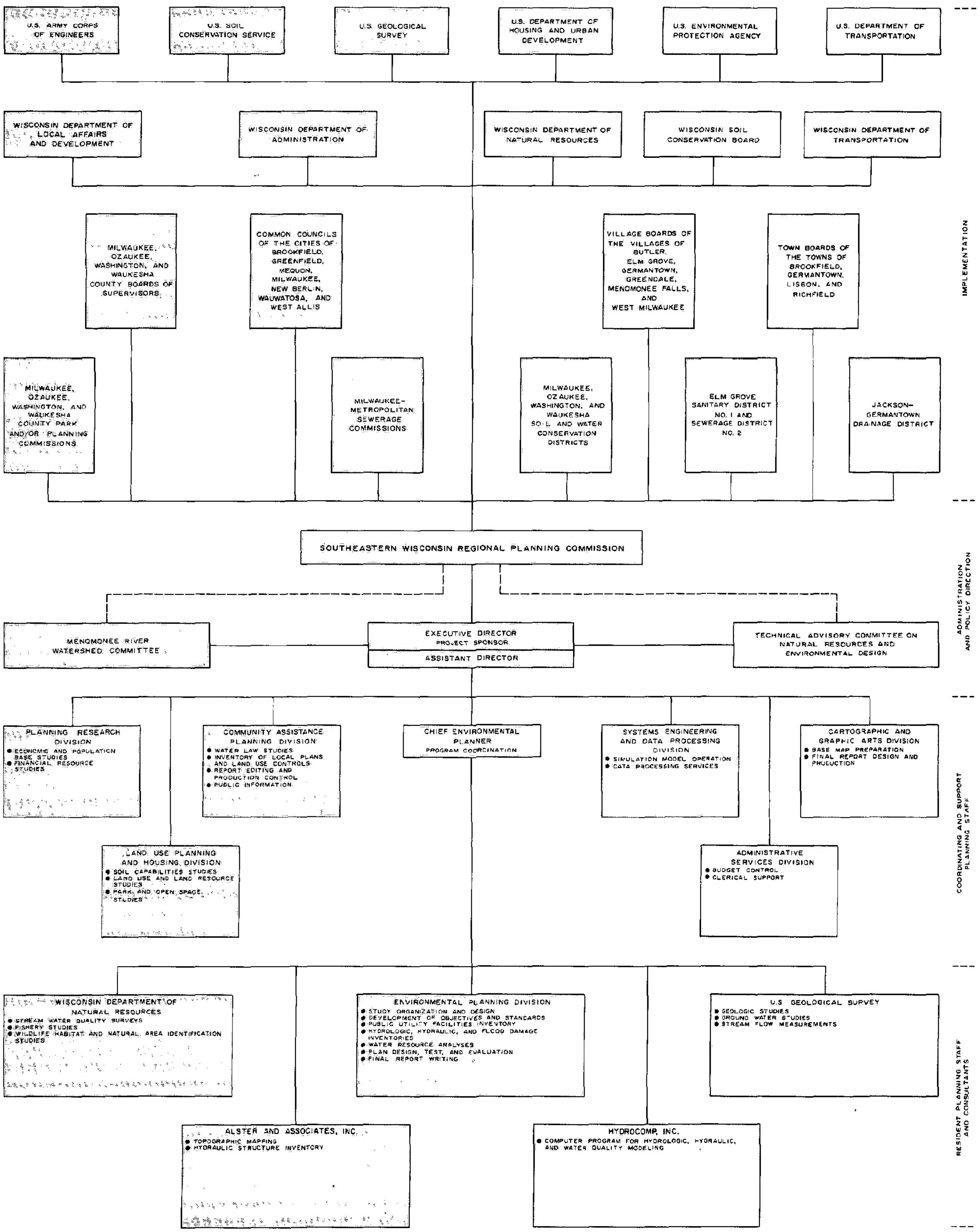
The first type of advisory committee, which functions as a part of the organization created by the Commission for watershed planning, is the Technical Advisory Committee on Natural Resources and Environmental Design. This Committee was established in January 1962 and includes representatives from governmental agencies with active resource planning, development, research, or management programs in southeastern Wisconsin. The full Committee membership is listed in Appendix B. The basic purpose of this Committee is to place the experience, expertise, and resources of the represented federal, state, and local agencies at the disposal of the study, and to ensure that the planning objectives and design criteria of these agencies are recognized and incorporated to the fullest extent possible into the watershed planning work.

The second type of advisory committee, which functions as a part of the organization created by the Commission for watershed planning, is the Menomonee River Watershed Committee. The basic purpose of this important Committee, which was established in March 1968, is to actively involve the various governmental bodies, technical agencies, and private interest groups within the watershed in the planning study. The Committee assists the Commission in determining and coordinating basic policies involved in the conduct of the study and in the resultant plans and plan implementation programs. Active involvement of local public officials in the watershed planning program through this Committee is particularly important to any ultimate implementation of the watershed plans, in light of the advisory role of the Commission in shaping regional and subregional development. The Watershed Committee performs an important educational function in familiarizing local leadership within the watershed with the study and its findings, in generating an understanding of basic watershed development objectives and implementation procedures, and in encouraging plan implementation. The Watershed Committee has proven to be a very valuable advisory body to the Commission and its staff throughout the conduct of the Menomonee River watershed planning program.

The watershed planning work program has been conducted by the resident Commission staff, supplemented as needed by contractual services provided by one federal agency, one state agency, and two consulting engineering firms. The Commission staff managed and directed all phases of the engineering and planning work. More specifically, the Commission staff was responsible for and provided the principal inputs to the detailed study design; formulation of watershed development objectives, principles and standards; conduct of inventories; analysis of inventory

Figure 2

ORGANIZATIONAL STRUCTURE OF THE MENOMONEE RIVER WATERSHED STUDY



Source: SEWRPC.

data and information to identify urban needs and resource problems and capabilities; synthesis and evaluation of alternative plan elements; and report writing.

The efforts of the Commission's professional and supporting staff were supplemented with the services of specialists in selected areas, including surveying and photogrammetry, groundwater analysis, streamflow measurement, surface water quality monitoring, fishery studies, wildlife habitat and natural area identification, and hydrologic-hydraulic-water quality modeling. The contribution of these selected specialists was necessary to the successful and efficient completion of the complex, interdisciplinary watershed planning program. Contractual agreements were executed, therefore, with the U. S. Geological Survey, the Wisconsin Department of Natural Resources, Alster and Associates, Inc., and Hydrocomp, Inc. Each of these organizations was selected by the Commission for participation in the study by virtue of its particular skills and experience in specialized phases of watershed planning.

Under the study, the U. S. Geological Survey was responsible for those elements of the study which related to groundwater resources and groundwater-surface water relationships. The Geological Survey also provided selected streamflow measurements and surface water quality data. The Wisconsin Department of Natural Resources was responsible for natural resource-related aspects of the study; more specifically, the conduct of three synoptic water quality surveys, a fishery study, a wildlife habitat study, and the delineation of unique natural areas. Alster and Associates, Inc., was responsible for the conduct of the necessary horizontal and vertical control surveys within the watershed, the preparation of large-scale topographic maps, and the provision of selected physical data on selected hydraulic structures in the watershed. Hydrocomp, Inc. provided one of the computer programs used in simulating the hydrologic, hydraulic, and water quality characteristics of the watershed surface water system, and assisted the SEWRPC staff in installing and operating that program on the Commission computer system.

Scheme of Presentation

The major findings and recommendations of the Menomonee River watershed planning program are documented and presented in this report. The report first sets forth the basic concepts underlying the study and the factual findings of the extensive inventories conducted under the study. It identifies and to the extent possible quantifies the developmental and environmental problems of the watershed, and sets forth forecasts of future economic activity, population growth, and land use and concomitant environmental problems. The report presents alternative plan elements relating to floodland management, pollution abatement, park and open space needs, and land use, and sets forth a recommended plan for the development of the watershed based upon regional and watershed development objectives adopted by the Watershed Committee and the Commission. In addition, it contains financial and institutional analyses and specific recommendations for plan implementation. This report is intended to allow careful, critical review of the alternative plan elements by public officials, agency staff personnel, and citizen leaders within the watershed, and to provide the basis for plan adoption and implementation by the federal, state, and local agencies of government concerned.

This report can only summarize briefly the large volume of information assembled in the extensive data collection, analysis, and forecasting phases of the Menomonee River watershed study. Although the reproduction of all of this information in report form is impractical due to the magnitude and complexity of the data collected and analyzed, all of the basic data are on file in the Commission offices and are available to member units and agencies of government and to the general public upon specific request. This report, therefore, serves the additional purpose of indicating the types of data which are available from the Commission and which may be of value in assisting federal, state, and local units of government and private investors in making better decisions about community development within the Region.

Chapter II

BASIC PRINCIPLES AND CONCEPTS

INTRODUCTION

Watershed planning is not new. Plans have been developed in the past for many watersheds, both large and small, throughout the United States. Most of these plans, however, have been developed either to meet the needs of one or more specific revenue-producing functions such as irrigation or hydroelectric power generation, or to fulfill a single-purpose requirement for which specific benefits are assignable to existing properties, such as flood control or soil and water conservation. Generally speaking, watershed planning efforts have traditionally employed single, although sometimes multiple, means to achieve single or relatively narrow goals, with emphasis on those goals which could be directly measured in monetary terms.

The application of comprehensive planning principles and practices to water and water-related resource problems as described in this report, however, is a relatively new concept. Consequently, at the time the Commission undertook its first comprehensive watershed planning program, that for the Root River watershed, little practical experience had been accumulated in such comprehensive watershed planning, and widely accepted principles governing such planning had not been established. Moreover, the need to carry out comprehensive watershed planning as an integral part of a broader regional planning effort required the adaption and modification of the limited body of watershed planning experience which did exist to the specific needs of the Root River watershed planning program.

These factors occasioned, as part of the Root River watershed study, the development of a unique approach to watershed planning, an approach which proved to be sound and which was, therefore, adopted for use in subsequent studies for the Fox, Milwaukee, and Menomonee River watersheds. This approach can only be explained in terms of the conceptual relationships existing between watershed planning and regional planning, and the basic principles applicable to watershed planning set within the framework of regional planning. Only after this foundation of conceptual relationships and applicable principles has been established can the specific problems of the Menomonee River watershed and the recommended solution to these problems, as presented herein, be properly understood.

THE WATERSHED AS A PLANNING UNIT

Planning relating to water and water-related natural resources could conceivably be carried out on the basis of various geographic units, including areas defined by governmental jurisdictions, economic linkages, or watershed boundaries. None of these are perfect as a water and water-related resources planning unit. There are many advantages to selection of the watershed as a water and water-related resources planning unit, however, since many problems relating to both rural and urban development as well as to natural resource conservation are water-oriented.

Floodland management measures and flood control and storm drainage facilities should form a single integrated system over an entire watershed. Streams and watercourses, as hydraulic systems, must be capable of carrying both present and future runoff loads generated by changing land use and changing water control facility patterns within the watershed. Therefore, flood control and storm drainage problems and facilities can best be considered on a watershed basis. Drainage and flood control problems, however, are closely related to other land and water use problems. Consequently, floodland protection, park and related open space reservation, and other recreational needs that are related to surface water resources also can best be studied on a watershed basis.

Water supply and sewerage frequently involve problems that cross watershed boundaries, but strong watershed implications are involved if the source of water supply comes from the surface water resources of the watershed or if the sewerage systems discharge pollutants into the surface water system. Groundwater divides do not necessarily coincide with surface water divides, and therefore planning for groundwater use and protection must incorporate both intrawatershed and interwatershed considerations. Changes in land use and transportation requirements are ordinarily not controlled primarily by watershed factors, but can have major effects on watershed problems. The land use and transportation patterns may significantly affect the amount and spatial distribution of the hydraulic and pollution loadings to be accommodated by water control facilities. In turn, the water control facilities and their effect upon the histroic floodlands determine to a considerable extent the use to which such land areas may be put.

Finally, the related physical problems of a watershed tend to create a strong community of interest among the residents of the watershed, and citizen action groups can readily be formed to assist in solving water-related problems. The existence of a community of interest around which to organize enlightened citizen participation in the planning process is one of the most important factors contributing to the success of such a process.

It may be concluded, therefore, that the watershed is a logical areal unit to be selected for resources planning purposes, provided that the relationships existing between the watershed and the surrounding region are recognized. Accordingly, the SEWRPC regional planning program embodies a recognition of the need to consider watersheds within the Region as rational planning units if workable solutions are to be found to intensifying interrelated land and water use problems.

The foregoing discussion implies that the term watershed may have two meanings. Defined in a strictly physical sense, a watershed is simply a geographic area of overland drainage contributing surface runoff to the flow of a particular stream or watercourse at a given point. Under this definition, the terms watershed and drainage basin are synonymous. The meaning of the term watershed may be expanded to include planning concepts, however, by adding to the above definition the phrase: whose natural and man-made features are so interrelated and mutually interdependent as to create a significant community of interest among its residents. This expanded definition of the term watershed contains within it the characteristics which a drainage basin, such as that of the Menomonee River, must exhibit if it is to form a rational unit for comprehensive water resources planning. This expanded definition, moreover, had a particularly important impact upon the geographic area to be encompassed in a study of the Menomonee River watershed by the Regional Planning Commission, for careful consideration of the communities of interest involved led the Commission to exclude from its delineation of the Menomonee River watershed the drainage areas of the Milwaukee and Kinnickinnic Rivers as well as the estuary shared by all three of these streams. It is thus recognized that a watershed is far more than a system of interconnected waterways and floodlands, which, in fact, comprise only a small proportion of the total watershed area. Land treatment measures, soil and water management practices, and land use over the entire watershed, as well as all related water resource problems, are of major importance in the proper development of watershed resources.

RELATIONSHIP OF WATERSHED TO REGION

Although recognizing the importance of the watershed as a rational planning unit within the Region, the SEWRPC planning program also recognizes the necessity to conduct individual watershed planning programs within the broader framework of areawide, comprehensive regional planning. This is essential for two reasons. First, areawide urbanization and the developmental and environmental problems resulting from such urbanization indiscriminately cross watershed boundaries and exert an overwhelming external influence on the physical development of the affected watershed. Second, the meandering pattern of natural watershed boundaries rarely, if ever, coincides with the artificial, generally rectangular boundaries of minor civil divisions and special-purpose districts.

Important elements of the necessary comprehensive, areawide planning program have been provided by the regional land use-transportation study and by other areawide planning programs of the Commission such as the regional sanitary sewerage system planning program. Conversely, within the context of the regional planning program, the comprehensive watershed planning programs provide, within the limits of each watershed, one of the key elements of a comprehensive regional development plan, namely, a long-range plan for water-related community facilities. While the proposed watershed plans may be centered on water quality and flood control facilities and on floodland management measures, it must be recognized that these facility plans and management measures must be prepared in consideration of the related problems of land and water use and of park and related open space reservation needs. Recognition of the need to relate water control facility plans and management measures to areawide regional development plans is the primary factor which determines the unique nature of the Commission watershed planning efforts. Ultimate completion of planning studies covering all of the watersheds within the Region will provide the Commission with a framework of plans encompassing drainage, flood control, and water pollution control facilities as well as floodland management measures properly related to comprehensive, areawide development plans, and will make significant contributions to the separation of a framework of regional community facility plans for parks and related open spaces and for water supply and sewerage facilities.

THE WATERSHED PLANNING PROBLEM

Although the water-related resource planning efforts of the Commission are focused on the watershed as a rational planning unit, the watershed planning problem is closely linked to the broader problem of resource conservation. Society has always had need to be concerned with resource conservation, but the need for such concern is greater today than ever before, and grows, as does the need for regional planning, out of the rapid population growth and urbanization of the nation, the state, and the Region. Increasing urbanization has, moreover, changed the nature of the resource conservation problem.

In the past, conservation was largely concerned with the protection of wilderness areas and possible future shortages of some resources resulting from chronic mismanagement. The problem which conservation now faces concerns mainly the kind of environment being created by the ever increasing areawide diffusion of urban development over large regions and the relentless pursuit of an ever higher material standard of living. Regional settlement patterns so far have not been determined by design but by economic expedience, and have failed to recognize the existence of a limited resource base to which urban development must be carefully adjusted if severe environmental problems are to be avoided. If increasing areawide urbanization is to work for the benefit of man and not to his detriment, adjustment of such urban development to the ability of the resource base to sustain and support it, thereby maintaining the quality of the environment, must become a major physical development objective for urbanizing regions.

Enlightened public officials and citizen leaders are gradually becoming aware of this new and pressing need for conservation. This growing awareness is often accelerated as the result of a major disaster or of the imminent threat of such a disaster. Even in such cases, however, the magnitude and degree of the interrelationship of resource problems may not always be fully realized. In many cases, such as in the Menomonee River watershed, the initial concern with the growing resource problems is centered in such highly visible problems as flooding and water pollution.

Growing urbanization is causing increasing concern on the part of public officials, citizen leaders, engineers, and planners with water and water-related resource problems. The manner in which these problems are ultimately resolved will involve many important public policy determinations. These determinations must be made in view of an urbanizing Region which is constantly changing, and therefore should be based upon a comprehensive planning process able to objectively scale the changing resource demands against the ability of the limited natural resource base to meet these demands. Only within such a planning process can the effects of different land and water use and water control facility construction proposals be evaluated, the best course of action intelligently selected, and the available funds most effectively invested.

The ultimate purposes of such a planning process are twofold: 1) to permit public evaluation and choice of alternative resource conservation and development policies and plans, and 2) to provide, through the medium of a long-range plan for water-related community facilities, for the full coordination of local, state, and federal resource development programs within the Region and within the various watersheds of the Region. Important among the goals to be achieved by this process are the protection of floodlands; the protection of water quality and supply; the preservation of land for park and open space; and, in general, promotion of the wise and judicious use of the limited land and water resources of the Region and its watershed.

BASIC PRINCIPLES

Based upon the foregoing considerations, eight basic principles were developed under the Root River watershed study, which together form the basis for the specific watershed planning process applied by the Commission in that study. These same principles were used in the Fox and Milwaukee River watershed studies, and provide the basis for the planning process applied in the Menomonee River watershed study:

1. Watersheds must be considered as rational planing units if workable solutions are to be found to water and water-related resource problems.

2. A comprehensive, multipurpose approach to water resource development and to the control and abatement of the water-related problems is preferable to a single-purpose approach.

3. Watershed planning must be conducted within the framework of a broader areawide regional planning effort, and watershed development objectives must be compatible with, and dependent upon, regional development objectives and plans based on those objectives.

4. Water control facility planning must be conducted concurrently with, and cannot be separated from, land use planning.

5. Both land use and water control facility planning must recognize the existence of a limited natural resource base to which urban and rural development must be properly adjusted to ensure a pleasant and habitable environment.

6. The capacity of each water control facility in the integrated watershed system must be carefully fitted to the present and probable future hydraulic loads, and the hydraulic performance and hydrologic feasibility of the proposed facilities must be determined and evaluated.

7. Primary emphasis should be placed on in-watershed solutions to water resource problems. The export of water resource problems to downstream areas is unwise on a long-range and regional basis.

8. Plans for the solution of watershed problems and development of resources should offer as flexible an approach as possible in order to avoid "dead-end" solutions and provide latitude for continued adaptation to changing conditions.

THE WATERSHED PLANNING PROCESS

Based upon the foregoing principles, the Commission has developed a seven-step planning process by which the principal functional relationships existing within a watershed can be accurately described, both graphically and numerically; the hydrologic, hydraulic, and water quality characteristics of the basin simulated; and the effect of the different courses of action with respect to land use and water control facility development evaluated. The watershed planning process not only provides for the integration of all of the complex planning and engineering studies required to prepare a comprehensive watershed plan, but, importantly, provides a means whereby the various private and public interests concerned may actively participate in the plan preparation. The process thus provides a mechanism for resolving actual and potential conflicts between such interests; a forum in which the various interests may better understand the various interrelated problems of the watershed and the alternative solutions available for such problems; and finally, a means whereby all watershed interests may become committed to implementation of the best alternative for the resolution of the problems.

The seven steps involved in this planning process are: 1) study design, 2) formulation of objectives and standards, 3) inventory, 4) analysis and forecast, 5) plan synthesis, 6) plan test and evaluation, and 7) plan selection and adoption. Plan implementation, although necessarily beyond the foregoing planning process, must be considered throughout the process if the plans are to be realized.

The principal results of the above process are land use and water control facility plans scaled to future land use and resource demands and consistent with regional development objectives. In addition, the process represents the beginning of a continuing planning effort that permits modification and adaptation of the plans and the means of implementation to changing conditions. Each step in this planning process includes many individual operations which must be carefully designed, scheduled, and controlled to fit into the overall process. An understanding of this planning process is essential to an appreciation and understanding of the results. Each step in the process, together with its major component operations, is diagrammed in Figure 3 and described briefly below.

Study Design

Every planning program must embrace a formal structure or study design so that the program can be carried out in a logical and consistent manner. This study design must specify the content of the fact-gathering operations, define the geographic area for which data will be gathered and plans prepared, outline the manner in which the data collected are to be processed and analyzed, specify requirements for forecasts and forecast accuracy, and define the nature of the plans to be prepared and the criteria to be used in their evaluation and adoption.

The need for, and objectives of, the Menomonee River watershed study were set forth in the Menomonee River Watershed Planning Program Prospectus prepared by the Commission staff under the direction of the Menomonee River Watershed Committee. The Prospectus also identified major work elements to be included in the comprehensive watershed study and set forth in the study design framework. In addition, a public hearing was held by the Watershed Committee on April 19, 1972, to elicit public opinions concerning the need for, objectives of, and scope and content of the proposed watershed study. The testimony presented at this hearing, which was attended by 54 interested persons, is set forth in the minutes of the hearing, dated May 1, 1972. The Prospectus, supplemented by the testimony presented at the initial public hearing on the Menomonee River watershed study, was used by the Commission staff to prepare a detailed study design which was presented to the Menomonee River Watershed Committee for review and approval prior to initiation of the work.

The staff of the Southeastern Wisconsin Regional Planning Commission expanded and refined this study design during the course of the study as a result of continuous staff level communication with those governmental agencies and private consultants contributing certain specialized services to the Menomonee River watershed planning program, and with the watershed committee.

Formulation of Objectives and Standards

In its most basic sense, planning is a rational process for establishing and meeting objectives. The formulation of objectives is, therefore, an essential task to be undertaken before plans can be prepared. In order to be useful in the regional and watershed planning process, the objectives to be defined must not only be clearly stated and logically sound, but must also be related in a demonstrable way to alternative physical development proposals. This is necessary because it is the duty and function of the Commission to prepare a comprehensive plan for the physical development of the Region and its component parts, and more particularly, because it is the objective of the Menomonee River watershed planning study to prepare one of the key elements of such a physical development plan—a long-range plan for water-related community facilities. Only if the objectives are clearly relatable to physical development and subject to objective test can a choice be made from among alternative plans in order to select that plan which best meets the agreed-upon objectives. Finally, logically conceived and well-expressed objectives must be translated into detailed design standards to provide the basis for plan preparation, test, and evaluation. Because the formulation of objectives and standards involves both technical and nontechnical policy determinations, all objectives and standards were carefully reviewed and adopted by the Menomonee River Watershed Committee, the Technical Advisory Committee on Natural Resources and Environmental Design, and the Commission.

The objectives and standards ranged from general development goals for the watershed as a whole, some of which were superimposed on the watershed study from the regional land-use transportation planning program and the regional sanitary sewerage system planning program, to detailed engineering and planning analytical procedures and design criteria covering rainfall intensity-duration-frequency relationships; digital computer simulation of hydrology; hydraulics of water quality; flood frequency analyses; design floods; water quality parameters; recreational facilities; and economic and financial analyses.

Inventory

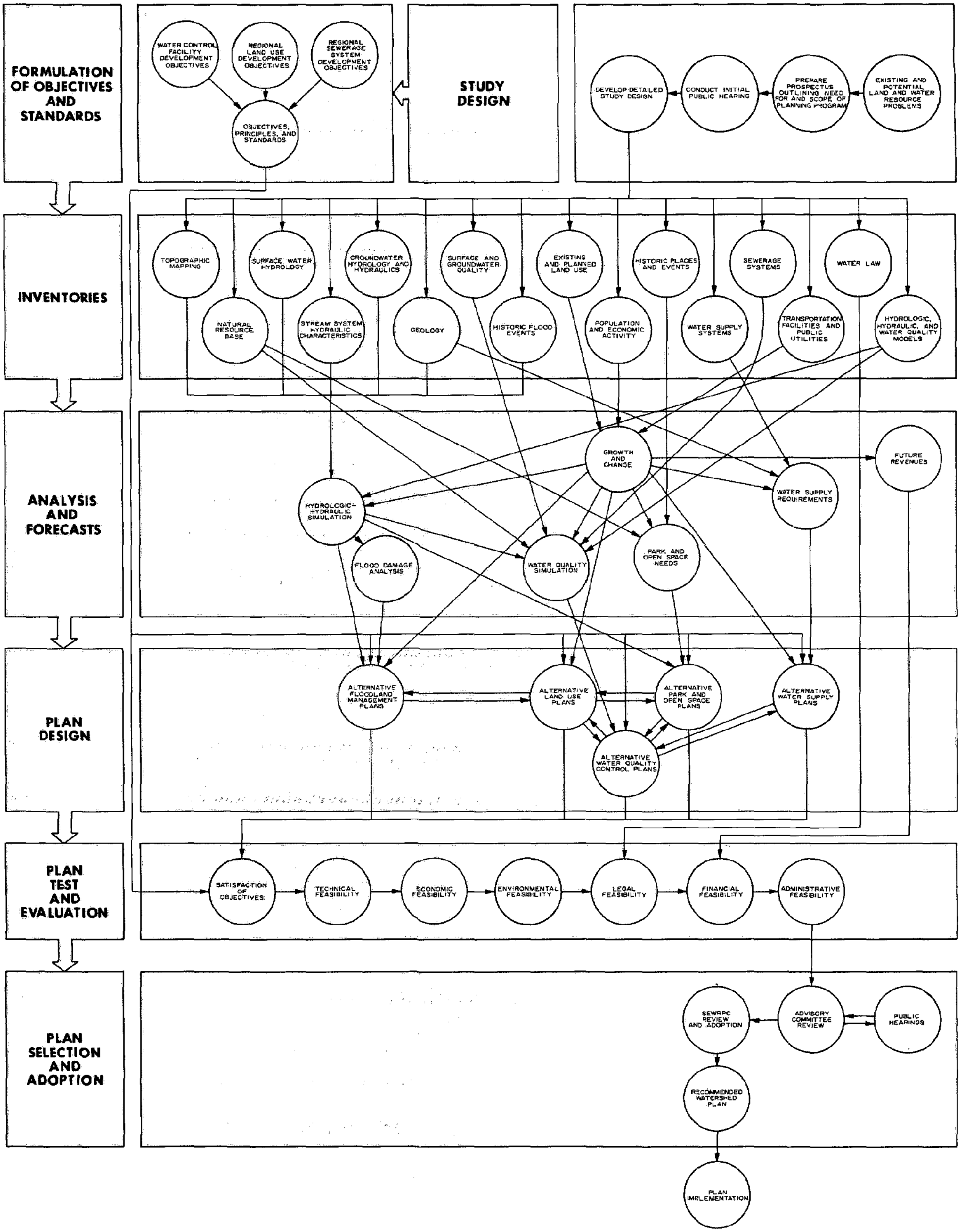
Reliable basic planning and engineering data collected on a uniform, watershed-wide basis are absolutely essential to the formulation of workable development plans. Consequently, inventory growing out of the study design becomes the first operational step in any planning process. The crucial need for factual information in the planning process should be evident, since no intelligent forecasts can be made or alternative courses of action selected without knowledge of the historical and current state of the system being planned.

The sound formulation of comprehensive watershed development plans requires that factual data must be developed on the quantity of surface and ground water, precipitation, hydraulic characteristics of the stream system, historic flooding, flood damages, water quality and wastewater sources, water use, soil capabilities, land use, economic activity, population, recreation facilities, fish and wildlife habitat, unique natural areas, historic sites, water supply and sewerage systems and other public utilities, and water law.

In the Menomonee River watershed study, the most expedient methods of obtaining adequate information of the necessary quality were followed. These included

Figure 3

GENERAL STEPS IN A COMPREHENSIVE WATERSHED PLANNING PROGRAM



Source: SEWRPC.

review of prior publications, perusal of agency files, personal interviews with private citizens and public officials, committee meetings of staff and technical advisors, and original field investigations.

Analysis and Forecast

Inventories provide factual information about historical and present situations, but analyses and forecasts are necessary to provide estimates of future needs for land, water, and water control facilities. These future needs must be determined from a sequence of interlocking forecasts. Economic activity and population forecasts enable determination of future growth within the watershed, which, in turn, can be translated into future demands for land, other resources, and water control facilities. These future demands can then be scaled against the existing supply and plans formulated to meet deficiencies.

To illustrate the complexity of this task in comprehensive watershed planning, consider that to prepare a forecast of future floodland management and flood control facility needs it was necessary to analyze and to interrelate the following factors: precipitation characteristics; relationship between basin morphology and runoff; effect of urbanization and soil properties on runoff volume and timing; effect of the hydraulic characteristics of the stream network on streamflow; relationships between streamflow, flood stage, and frequency of flood occurrence; seasonal influence; and influence of floodland storage and conveyance.

Two important considerations involved in the preparation of the necessary forecasts are the target date and accuracy requirements. Both the land use pattern and the floodland management measures, particularly water control facilities, must be planned for anticipated demand at some future point in time. In the planning of water control facilities, this "design year" is usually established by the expected life of the first facilities to be constructed in implementation of the plan. Although it may be argued that the design year for land use development should be extended further into the future than that for facilities because of the basic irreversibility of many land development decisions, practical considerations dictate that the land use planning design year be scaled to the facility design year requirement. In the Menomonee River watershed study, the necessary forecast period was set as approximately 30 years, both as a very conservative approximation of facility life and as a means for locking the watershed forecast periods into the previously determined regional land use-transportation study forecast periods.

Forecast accuracy requirements depend on the use to be made of the forecasts. As applied to land use and water control facility planning, the critical question relates to the effect of any forecast inaccuracies on the basic structure of the plans to be produced. It is important to keep the forecast tolerances within that range wherein only the timing and not the basic structure of the plans will be affected.

Plan Synthesis

Plan synthesis or design forms the heart of the planning process. The most well-conceived objective; the most sophisticated data collection, processing, and analysis operations; and the most accurate forecasts are of little value if they do not ultimately result in sound plans. The outputs of each of the three previously described planning operations—formulation of objectives and standards, inventory, and forecast—become inputs to the design problems of plan synthesis.

The land use plan design problem consists essentially of determining the allocation of a scarce resource—land—between competing and often conflicting demands. This allocation must be accomplished so as to satisfy the aggregate needs for each land use and comply with all of the design standards derived from the plan objectives, all at a feasible cost. The water control facility plan design problem requires a similar reconciliation between hydrologic, hydraulic, and pollution loading derived from the land use plan; adopted facility design standards; existing facilities; and new facility costs.

Plan Test and Evaluation

If the plans developed in the design stage of the planning process are to be realized in terms of actual land use and water control facility development, some measures must be applied to quantitatively test alternative plans in advance of their adoption and implementation. The alternative plans must be vigorously subjected to all the necessary levels of review and inspection, including: 1) engineering and technical feasibility, 2) environmental impact, 3) economic and financial feasibility, 4) legality, and 5) political reaction and acceptability. Devices used to test and evaluate the plans range from the use of digital computer simulation programs to evaluate hydrologic-hydraulic responses under alternative plan elements through interagency meetings and public hearings. Plan test and evaluation should demonstrate clearly which alternative plans or portions of plans are technically sound, economically and financially feasible, legally possible, and politically realistic.

Plan Selection and Adoption

It is proposed for the Menomonee River watershed study to develop a land use plan representing a refinement of the adopted regional land use plan. This land use plan is supported by various combinations of water control facility system plans for both flood control and pollution abatement, thus providing a number of alternative watershed development plans. The desirability of the recommended comprehensive plan is supported by an analysis of some of the consequences that may be expected under conditions of uncontrolled development.

The general approach contemplated for the selection of one plan from among alternatives is to proceed through the use of the Menomonee River Watershed Committee structure, interagency meetings, and informational meetings and hearings to a final decision and plan adoption by the Commission in accordance with the provisions of the state enabling legislation. The role of the Commission is to recommend the final plan to federal, state, and local units of government and private investors for their consideration and action. The final decisive step to be taken in the process is the acceptance or rejection of the plan by the local governmental units concerned, and subsequent plan implementation by public and private action. Therefore, plan selection and adoption must be founded in the active involvement of the various governmental bodies, technical agencies, and private interest groups concerned with development in the watershed. The use of advisory committees and both formal and informal hearings appears to be the most practical and effective procedure for achieving such involvement in the planning process, and of openly arriving at agreement among the affected governmental bodies and agencies on objectives and on a final watershed plan which can be cooperatively adopted and jointly implemented.

Chapter III

DESCRIPTION OF THE WATERSHED
MAN-MADE FEATURES AND THE NATURAL RESOURCE BASE

INTRODUCTION

A watershed is a complex of natural and man-made features which interact to comprise a changing environment for all life. Thus, the water resource and water resource related problems of the Menomonee River watershed, as well as the ultimate solutions to those problems, are a function of the activities of man within the watershed, and of the ability of the underlying natural resource base to sustain those activities. The watershed may be viewed as a large ecosystem composed of natural resources, man-made features, and the human population, all of which interact to comprise a changing environment for life. Future changes in that ecosystem, and in particular the favorable or unfavorable impact of those changes on the quality of life within the watershed, will be largely determined by man's actions. This is especially true in the Menomonee River watershed where urban land uses can be expected to occupy a greatly increased proportion of the watershed in the future. Comprehensive watershed planning seeks to rationally direct the future course of human actions affecting the ecosystem so as to favorably affect the overall quality of life in the watershed.

The purpose of this chapter is to describe the existing ecosystem, that is, the natural resource base and man-made features, of the watershed, thereby establishing a factual base upon which the watershed planning process may build. This description of the watershed is presented in this chapter in two major sections, the first of which describes the man-made features and the second of which describes the natural resource base of the watershed.

DESCRIPTION OF THE WATERSHED: MAN-MADE FEATURES

The man-made features of a watershed, which are important to any consideration of its future development, include its political boundaries, land use pattern, public utility network, and transportation system. Together with the population residing in, and the economic activities taking place within the watershed, these features may be thought of as the socioeconomic base of the watershed. A description of this base is essential to sound watershed planning, for any attempt to protect and improve the environment must be founded in an understanding of not only the various demands for land and public facilities and resources generated by the population and economic activities of an area, but also the ability of the existing land use pattern and public facility systems to meet these demands.

In order to facilitate such understanding, a description of the socioeconomic base of the watershed is herein presented in five sections. The first section places the watershed into proper perspective as a rational planning unit within a regional setting by delineating its internal political and governmental boundaries and relating these boundaries to the Region as a whole. The second section describes the demographic and economic base of the watershed in terms of population size, distribution, and composition and in terms of commercial, industrial, and agricultural activity and employment levels and distribution. The third section describes the patterns of land use in the watershed in terms of historical development and 1970 conditions. The fourth and fifth sections describe the public utility and transportation facility systems within the watershed. A final section at the end of this chapter summarizes the information presented on the man-made features and activities as well as on the natural resource base.

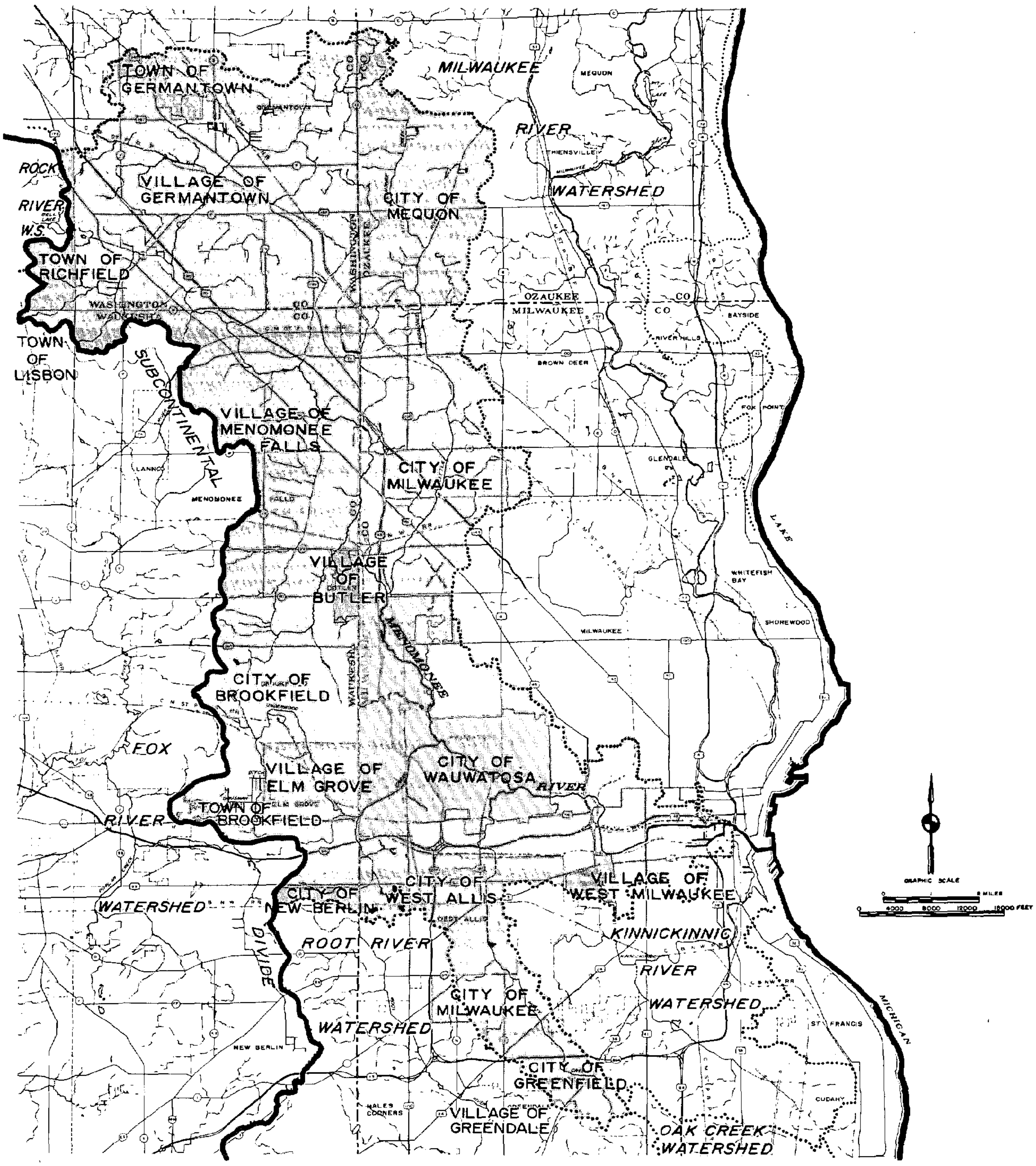
Regional Setting of the Watershed and Political Boundaries

The Menomonee River watershed, as shown on Map 3, is a surface water drainage unit, 137 square miles in areal extent, discharging to the Milwaukee River within the City of Milwaukee about 0.9 mile upstream of where the Milwaukee River enters Lake Michigan. The relatively narrow watershed is bounded on the north and east by the Milwaukee River watershed; on the south by the Kinnickinnic River, Root River, and Oak Creek watersheds; and on the west by the Rock and Fox River watersheds. The western boundary of the watershed marks the subcontinental divide which traverses the Region in a generally northwesterly-southeasterly direction, separating the Great Lakes-St. Lawrence River drainage basin from the Illinois-Mississippi River drainage basin.

The Menomonee River has its source in a large woodland-wetland area located in the northeastern corner of the Village of Germantown in Washington County. From its source, the river flows southeasterly through the Villages of Germantown and Menomonee Falls into Milwaukee County. It is joined by the Little Menomonee River in the City of Milwaukee near STH 100 and W. Hampton Avenue, the Little Menomonee River having its source in the City of Mequon in Ozaukee County and flowing southerly through the Cities of Mequon and Milwaukee to its junction with the Menomonee River. From its junction with the Little Menomonee, the Menomonee River flows southeasterly through the Cities of Milwaukee and Wauwatosa to be joined by Underwood Creek near W. North Avenue, which creek drains portions of the Cities of Wauwatosa, Brookfield, West Allis, and New Berlin, as well as the Village of Elm Grove and the Town of Brookfield. Honey Creek, which drains portions of the Cities of Milwaukee, Wauwatosa, West Allis, and Greenfield and the Village of Greendale, joins the Menomonee River from the south near 72nd Street. From its junction

Map 3

THE MENOMONEE RIVER WATERSHED



The Menomonee River watershed is a 137 square mile natural surface water drainage basin located entirely within the seven-county Southeastern Wisconsin Region. The relatively narrow watershed is bounded on the north and east by the Milwaukee River watershed; on the south by the Kinnickinnic River, Root River, and Oak Creek watersheds; and on the west by the Rock and Fox River watersheds. Serious flooding and pollution problems exist within the watershed, problems which require a comprehensive study of the entire watershed for sound resolution.

Source: SEWRPC.

with Honey Creek, the Menomonee River continues to flow in a generally southeasterly direction through the Cities of Wauwatosa and Milwaukee, entering the Lake Michigan estuary at a low dam located at about N. 29th Street extended in the City of Milwaukee.

The Menomonee River watershed, which is wholly contained within the seven-county Southeastern Wisconsin Planning Region, is the fifth largest of the 11 distinct watersheds located wholly or partly within the Region. It comprises 5 percent of the total land and water area of the Region.

Civil Divisions: Superimposed upon the natural, meandering watershed boundary is a rectangular pattern of local political boundaries, as shown on Map 3. The watershed occupies portions of four of the seven counties comprising the Southeastern Wisconsin Region—Milwaukee, Waukesha, Washington, and Ozaukee—and portions or all of seven cities, six villages, and four towns. The area and proportion of the watershed lying within the jurisdiction of each of the 17 civil divisions as of 1970 are set forth in Table 1. Geographic boundaries of the civil divisions are an important factor which must be considered in any areawide planning effort, like the Menomonee River watershed planning program, since the civil divisions form the basic foundation of the decision-making framework within which intergovernmental environmental and developmental problems must be addressed.

Metropolitan Sewerage District of the County of Milwaukee: A special-purpose areawide unit of government having important responsibilities for provision of sanitary sewer service and sewage treatment and for water pollution control and authorization for flood control exists within the Milwaukee County portion of the watershed: the Metropolitan Sewerage District of the County of Milwaukee. The District is legally empowered to provide sanitary sewer service to the watershed area lying not only within Milwaukee County, but by contract, to almost all of the watershed area lying outside of Milwaukee County. Map 4 shows the area of the watershed within the geographic boundaries of the Metropolitan Sewerage District of the County of Milwaukee—56.1 square miles or 40.9 percent of the total area of the watershed—as well as the District contract service area within the watershed—76.7 square miles or 56.7 percent of the total area of the watershed. Therefore, 132.8 square miles, or 97 percent of the total area of the watershed, lie within the existing and potential service area of the Metropolitan Sewerage District of the County of Milwaukee.

The Metropolitan Sewerage District of the County of Milwaukee does, or based upon existing authorization, could, serve almost all of the in-watershed portions of the seven cities and six villages located within the watershed. Only four civil divisions within the watershed do not lie within the Metropolitan Sewerage District of the County of Milwaukee or its existing contract service area—the Towns of Richfield and Germantown in Washington County, and the Towns of Brookfield and Lisbon in Waukesha County.

The Metropolitan Sewerage District of the County of Milwaukee, with its extensive existing and potential contract service areas in the Ozaukee, Washington, and Waukesha County portions of the Menomonee River watershed, is important to the Menomonee River watershed planning program, since this agency provides a mechanism for resolving not only areawide surface water pollution problems, but also in the lower reaches of the watershed, drainage and flood control problems.

The Regional Planning Commission's recently completed and adopted regional sanitary sewerage system plan recommends the abandonment of the five municipal sewage treatment plants presently existing in the watershed—the two Village of Germantown plants, the two Village of Menomonee Falls plants, and the Village of Butler plant—after construction of the trunk sewers required to convey the sewage generated in the tributary drainage areas to the Jones Island and South Shore sewage treatment plants operated by the City of Milwaukee Sewerage Commission. Some of the sewer construction needed to effect this recommendation has already been accomplished, and the smaller of the two Village of Germantown sewage treatment plants was abandoned in November 1973.

Local Sanitary Districts: Two local, special-purpose units of government providing sanitary sewer service also exist within the watershed. The Village of Elm Grove Sanitary District No. 1 and Sewerage District No. 2, also shown on Map 4, lie within the contract service area of the Metropolitan Sewerage District of the County of Milwaukee. Encompassing a combined area of 3.25 square miles—the entire area of the Village of Elm Grove—each of these two separate districts contracts with the Metropolitan Sewerage District of the County of Milwaukee for the conveyance and treatment of sewage.

Local Drainage Districts: A portion of one special-purpose unit of government providing agricultural drainage services exists within the watershed—the Jackson-Germantown Drainage District. This district encompasses an area of less than 0.25 square mile of the Menomonee River watershed, with most of its 11 square mile area lying to the north in the Milwaukee River watershed. Small portions of four inactive drainage districts also lie just within the watershed boundary in the City of Mequon, the Village of Menomonee Falls, and the Town and City of Brookfield—the Ozaukee County Drainage District No. 10, the Ozaukee County Drainage District No. 4, the Tamarac Swamp Drainage District (official name unknown), and the Upper Fox-Poplar Creek Drainage District (official name unknown).

Soil and Water Conservation Districts: In Wisconsin, the boundaries of the Soil and Water Conservation Districts, which are special-purpose units of government having responsibilities for the promotion of good soil and water conservation practices, are coterminous with county boundaries. Therefore, four such soil and water conservation districts have jurisdiction over portions of the watershed. These districts provide a potential institutional structure for the abatement of nonpoint sources of water pollution, as well as for the abatement of drainage and flood control problems.

Table 1

AREAL EXTENT OF COUNTIES, CITIES, VILLAGES, AND TOWNS IN THE MENOMONEE RIVER WATERSHED: 1970

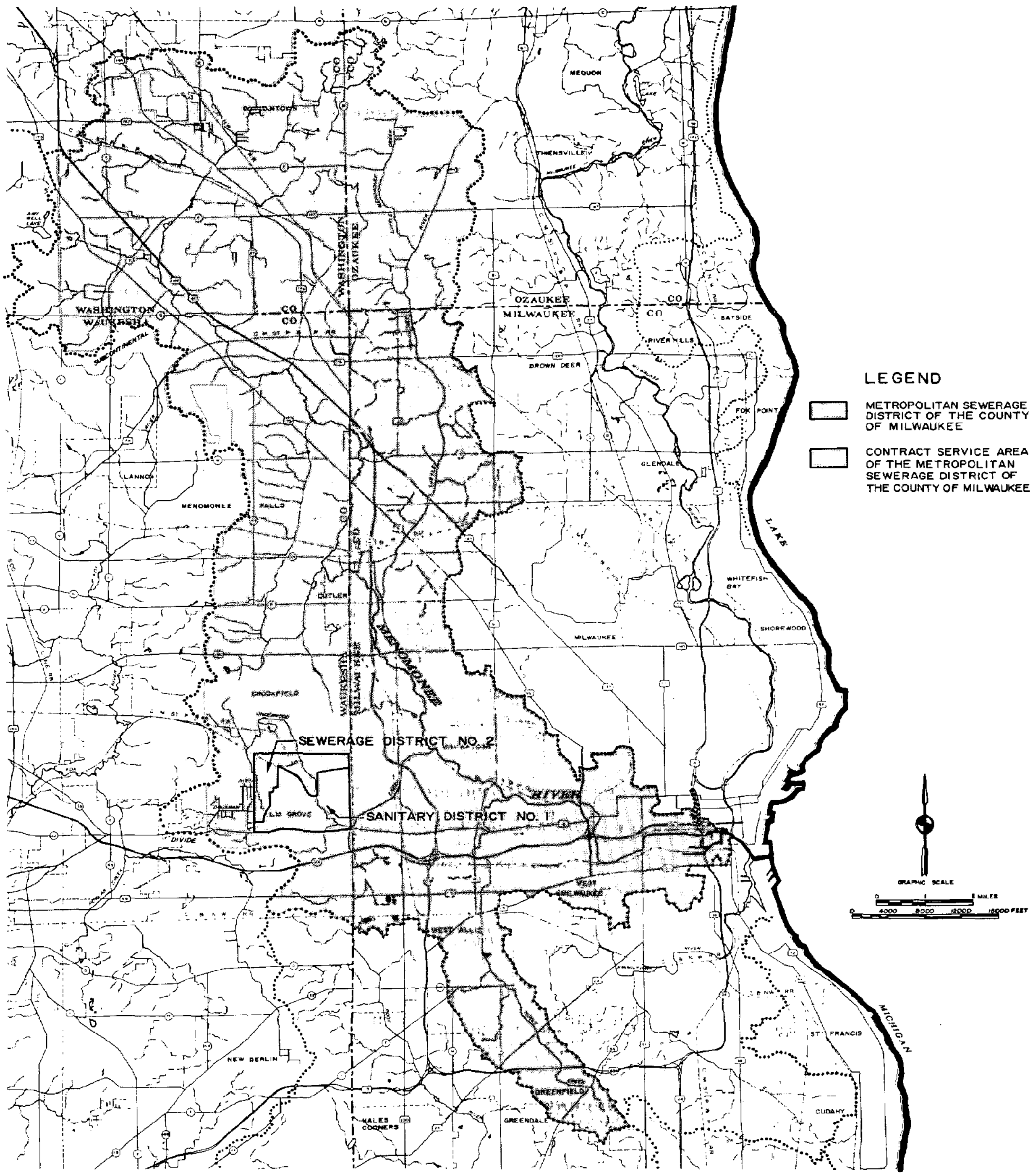
County or Civil Division	Total County or Civil Division Area (Square Miles)	County or Civil Division Area Included Within Watershed (Square Miles)	Percent of County or Civil Division Area Within Watershed	Percent of Watershed Area Within County or Civil Division
Milwaukee County . . .	242.19	56.11	23.17	40.89
Cities				
Greenfield	12.08	3.18	26.32	2.32
Milwaukee	95.96	31.06	32.37	22.63
Wauwatosa	13.23	13.23	100.00	9.64
West Allis	11.38	7.94	69.77	5.79
Villages				
Greendale	5.55	0.10	1.80	0.07
West Milwaukee . . .	1.11	0.60	54.05	0.44
Ozaukee County	234.49	11.88	5.07	8.66
City				
Mequon	46.88	11.88	25.34	8.66
Washington County . . .	435.50	31.84	7.31	23.20
City				
Milwaukee	0.01	0.01	100.00	0.01
Village				
Germantown	34.33	29.13	84.85	21.22
Towns				
Germantown	1.77	0.82	46.33	0.60
Richfield.	36.34	1.88	5.17	1.37
Waukesha County. . . .	580.66	37.40	6.44	27.25
Cities				
Brookfield	25.34	13.47	53.16	9.82
New Berlin	36.75	0.69	1.88	0.50
Villages				
Butler.	0.78	0.78	100.00	0.57
Elm Grove	3.25	3.25	100.00	2.37
Menomonee Falls. . .	33.50	18.66	55.70	13.60
Towns				
Brookfield	7.77	0.24	3.01	0.17
Lisbon	35.77	0.31	0.87	0.22
Total	- -	137.23[a]	- -	100.00

[a] *The areas in this table were determined by map delineation and measurement. Some data used in this report have been determined through approximating the watershed boundary by U. S. Public Land Survey quarter section and summing the quarter section totals. The actual measured watershed total is 137.23 square miles, or 87,827 acres. The watershed area as approximated by 538 quarter sections is 135.63 square miles, or 86,803 acres. The areas in this table differ somewhat from those set forth in Table 2 of the Menomonee River Watershed Planning Program Prospectus. The differences reflect a refined delineation of the watershed boundaries made under the watershed study, a delineation carefully reflecting the changes made in the natural boundaries of the watershed by the street and storm sewer construction accompanying urbanization.*

Source: SEWRPC.

Map 4

CONTRACT SERVICE AREA OF THE METROPOLITAN SEWERAGE DISTRICT OF THE COUNTY OF MILWAUKEE IN THE MENOMONEE RIVER WATERSHED



The Metropolitan Sewerage District of the County of Milwaukee is a special-purpose unit of government located within the Milwaukee County portion of the watershed. The District has responsibilities for sanitary sewer service, sewage treatment, and water pollution control, and has authorization to engage in flood control work. In addition to serving the watershed area within Milwaukee County, the District is legally empowered to provide, by contract, sanitary sewer service to almost all of the remainder of the watershed. Since about 97 percent of the Menomonee River watershed lies within the existing or potential service area of the Metropolitan Sewerage District of the County of Milwaukee, the District provides a good institutional structure for resolving basin-wide water pollution problems.

Source: SEWRPC.

Other Agencies Having Resource Responsibilities: Superimposed upon these local and areawide units and agencies of government are the state and federal governments, certain agencies of which have important responsibilities for resource conservation and management. These include the Wisconsin Department of Natural Resources; the University Extension of the University of Wisconsin; the State Board of Soil and Water Conservation Districts; the U. S. Department of the Interior, Geological Survey; the U. S. Environmental Protection Agency; the U. S. Department of Agriculture, Soil Conservation Service; the U. S. Army Corps of Engineers; and the International Joint Commission.

Demographic and Economic Base

Since the ultimate purpose of the watershed planning effort is to improve the environment for the resident population, an understanding of the size, characteristics, and spatial distribution of this population is basic to the watershed planning effort. The population must also be studied because of the direct relationships which exist between population levels and the demand for land, water, and other important elements of the natural resource base, as well as the demand for various kinds of transportation, utility, and community facilities and services. The size and other characteristics of the population of an area are greatly influenced by growth and other changes in economic activity. Population features and economic activity must, therefore, be considered together. It is important to note, however, that because the Menomonee River watershed is an integral part of a larger urbanizing Region, many of the economic forces that influence population growth within the watershed are centered outside the watershed proper. Thus, any economic analysis for watershed planning purposes must relate the economic activity within the watershed to the economy of the larger Region. Similarly, the size, other characteristics, and distribution of the population residing within the watershed must be viewed in relation to the similar features of the population within the Region as a whole and within adjacent regions.

Demographic Base: A study of the demographic base includes consideration of population size, population distribution, and population composition.

Population Size: The 1970 population of the watershed was estimated at 348,165 persons, or about 20 percent of the total population of the Region. As shown in Table 2 and Figures 4 and 5, the population of the watershed increased rapidly from 1900 to 1930 at rates similar to those of the Region, and substantially higher than those of the state and nation. From 1930 to 1940, the population growth rate within the watershed declined sharply, consistent with trends in the population growth of the Region, state, and nation, and reflecting the severe economic recession of the 1930s. From 1940 to 1950, the rate of population growth within the watershed approximated that of the Region and the nation, while it remained higher than that of the state. From 1950 to 1960, the population growth rate of the watershed rose along with that of the Region, and significantly exceeded the growth rates of the state and nation. From 1960 to 1970, the rate of growth of the watershed population declined along with that of the Region so as to parallel that of the state and nation.

Population Distribution: The 1950, 1960, and 1970 watershed population by county and civil division is presented in Table 3 and is graphically summarized by county in Figure 6. The greatest proportion of the Menomonee River watershed population resides in Milwaukee County, and although the number of persons living in the Milwaukee County portion of the watershed has continued to increase since 1950, the proportion of the total watershed population living there has steadily diminished over this 20-year period. In 1970, 278,887 persons, or 80 percent of the population of the watershed, lived in Milwaukee County, compared to 263,606 persons (85 percent) in 1960, and 230,808 persons (94 percent) in 1950. The largest absolute and proportional increase of watershed population from 1960 to 1970 for any county or civil division occurred in the Village of Menomonee Falls, where the population increased by 12,093 persons and the proportion of watershed residents residing in the village increased almost 3 percent, from 6 percent in 1960 to almost 9 percent in 1970.

The Ozaukee, Washington, and Waukesha County portions of the watershed all experienced both proportional and absolute gains in watershed population during the 1960 to 1970 period, with the Waukesha County portion of the watershed experiencing the largest absolute gain in population within the watershed—20,591 persons.

As shown on Map 5, a very wide range in population density exists within the Menomonee River watershed, ranging from less than 350 persons per gross square mile in the headwater areas of the watershed to 25,000 persons or more per gross square mile in the highly urbanized lower portions of the watershed. Areas of greatest population density—25,000 or more persons per gross square mile—occur within the City of Milwaukee. Most of the lower portion of the watershed within Milwaukee County exhibits population densities in excess of 3,500 persons per gross square mile, with the population density gradually decreasing in an upstream direction.

From 1960 to 1970, the overall population density of the watershed increased from 1,976 to 2,537 persons per square mile, an increase of 561 persons per square mile, or 28 percent. Overall 1970 watershed population density, as well as population density of cities, villages, and towns and the proportion of the watershed population residing in cities, villages, and towns, is presented in Table 4.

The population distribution of the watershed, with the dense concentration of people in the lower watershed area, combined with a rapid diffusion of population into the middle and upper reaches of the watershed, are factors contributing to developmental, environmental, and resource-related problems of the watershed. These problems will be discussed in greater detail in subsequent chapters of this report.

Table 2

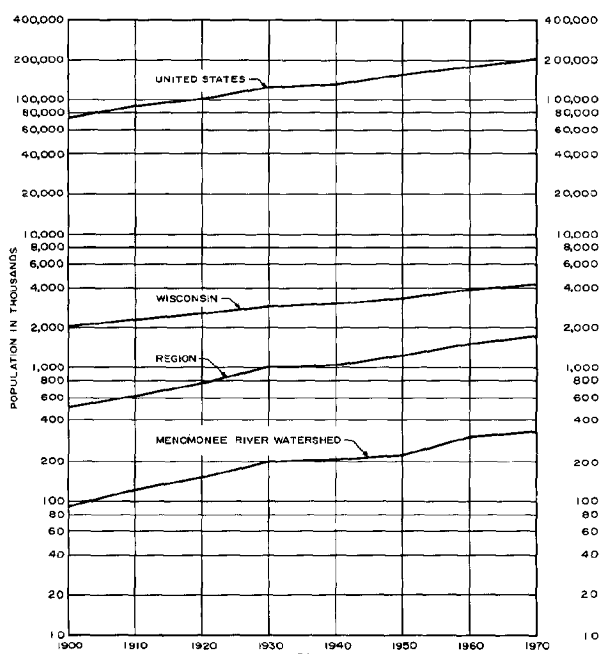
POPULATION OF THE MENOMONEE RIVER WATERSHED, THE REGION, WISCONSIN, AND THE UNITED STATES: SELECTED YEARS 1900-1970

Year	Population								Watershed Population as Percent of Regional Population
	Menomonee River Watershed		Region		Wisconsin		United States		
	Number	Percent Increase During Preceeding Decade	Number	Percent Increase During Preceeding Decade	Number	Percent Increase During Preceeding Decade	Number	Percent Increase During Preceeding Decade	
1900	94,917	--	501,808	--	2,069,042	--	75,994,575	--	19
1910	122,275	29	631,161	26	2,333,860	13	91,972,266	21	19
1920	151,271	24	783,681	24	2,632,067	13	105,710,620	15	19
1930	200,403	32	1,006,118	28	2,939,006	12	122,775,046	16	20
1940	213,295	6	1,067,699	6	3,137,587	7	131,669,270	7	20
1950	245,695	15	1,240,618	16	3,434,575	9	151,325,798	15	20
1960	309,240	26	1,573,620	27	3,952,771	15	179,323,175	18	20
1970	348,165	13	1,756,086	12	4,417,933	12	203,184,772	13	20

Source: U. S. Bureau of the Census and SEWRPC.

Figure 4

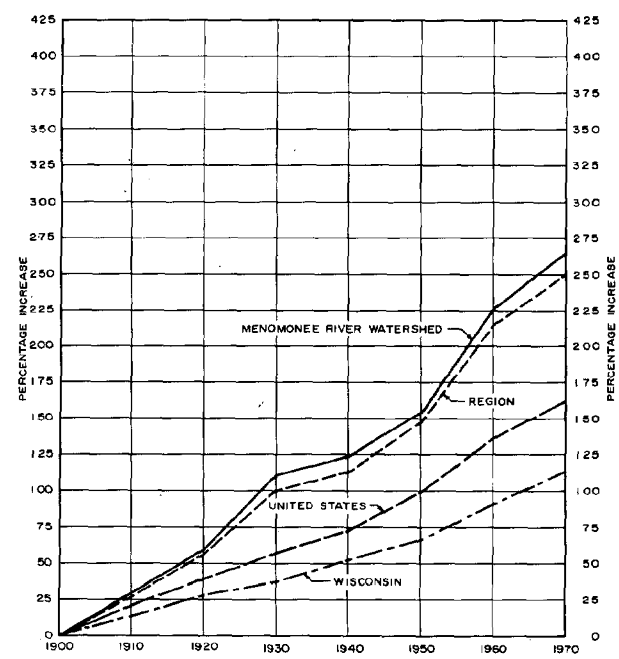
POPULATION OF THE MENOMONEE RIVER WATERSHED, THE REGION, WISCONSIN, AND THE UNITED STATES 1900-1970



Source: U. S. Bureau of the Census, and SEWRPC.

Figure 5

PERCENTAGE INCREASE IN POPULATION IN THE MENOMONEE RIVER WATERSHED, THE REGION, WISCONSIN, AND THE UNITED STATES: 1900-1970



Source: U. S. Bureau of the Census, and SEWRPC.

Table 3

POPULATION IN THE MENOMONEE RIVER WATERSHED BY COUNTY AND CIVIL DIVISION: 1950, 1960, and 1970

Civil Division	1950 Population Within Watershed	1950 Percent of Watershed Population	1960 Population Within Watershed	1960 Percent of Watershed Population	1970 Population Within Watershed	1970 Percent of Watershed Population
Milwaukee County	230,808	93.94	263,606	85.24	278,887	80.10
Cities						
Greenfield[a]	8,183	3.33	5,134	1.66	7,445	2.14
Milwaukee	143,250	58.30	155,191	50.18	165,258	47.47
Wauwatosa	51,741	21.06	56,923	18.41	58,676	16.85
West Allis	23,562	9.59	41,761	13.50	43,088	12.38
Villages						
Greendale	--[b]	--[b]	296	0.10	653	0.19
West Milwaukee	4,072	1.66	4,301	1.39	3,757	1.08
Ozaukee County	253	0.10	550	0.18	782	0.22
City						
Mequon[a]	253	0.10	550	0.18	782	0.22
Washington County	2,487	1.01	4,641	1.50	7,462	2.14
City						
Milwaukee	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]
Village						
Germantown	357	0.14	622	0.20	6,729	1.93
Towns						
Germantown	2,004	0.82	3,804	1.23	373	0.11
Richfield	126	0.05	215	0.07	360	0.10
Waukesha County.	12,147	4.95	40,443	13.08	61,034	17.53
Cities						
Brookfield[c].	--	--	13,354	4.33	18,581	5.34
New Berlin[a].	482	0.20	1,581	0.51	2,431	0.70
Villages						
Butler	1,047	0.43	2,166	0.70	2,261	0.65
Elm Grove[c].	--	--	4,994	1.61	7,201	2.07
Menomonee Falls[d] . . .	6,123	2.49	18,054	5.84	30,147	8.66
Towns						
Brookfield	4,491	1.83	287	0.09	383	0.11
Lisbon	4	--[e]	7	--[e]	30	0.01
Total	245,695	100.00	309,240	100.00	348,165	100.00

[a] *These areas were not incorporated until after the 1950 U. S. Census.*

[b] *Negligible.*

[c] *These areas were incorporated from parts of the Town of Brookfield after the 1950 U. S. Census.*

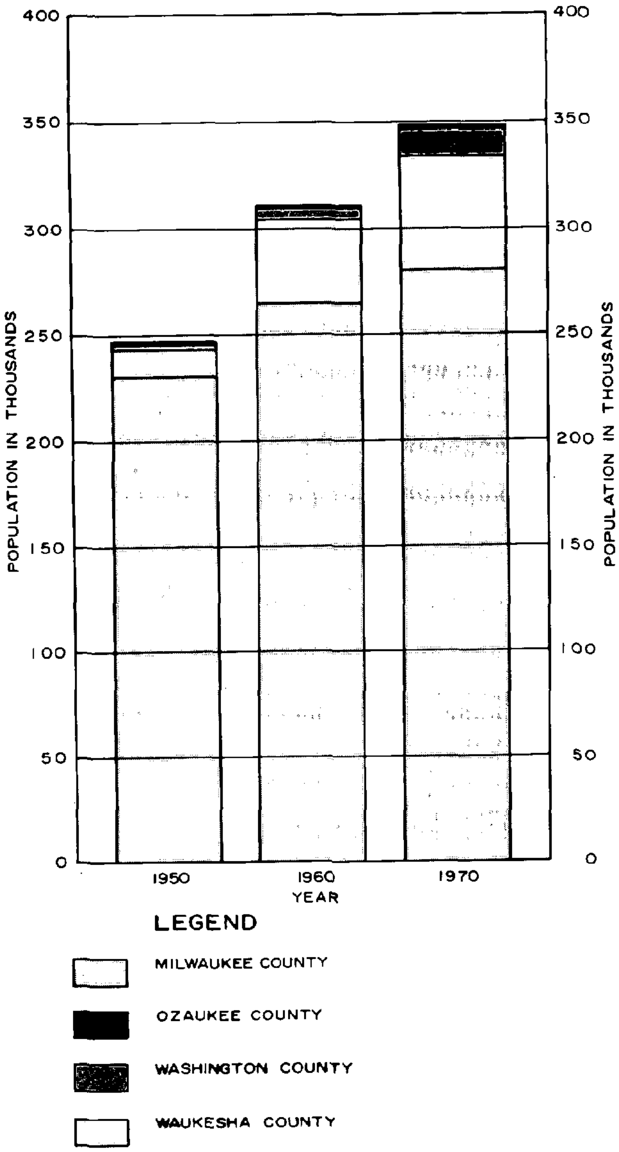
[d] *The Town of Menomonee is included in the village total for 1950.*

[e] *Less than 0.01 percent.*

Source: U. S. Census of Population and SEWRPC.

Figure 6

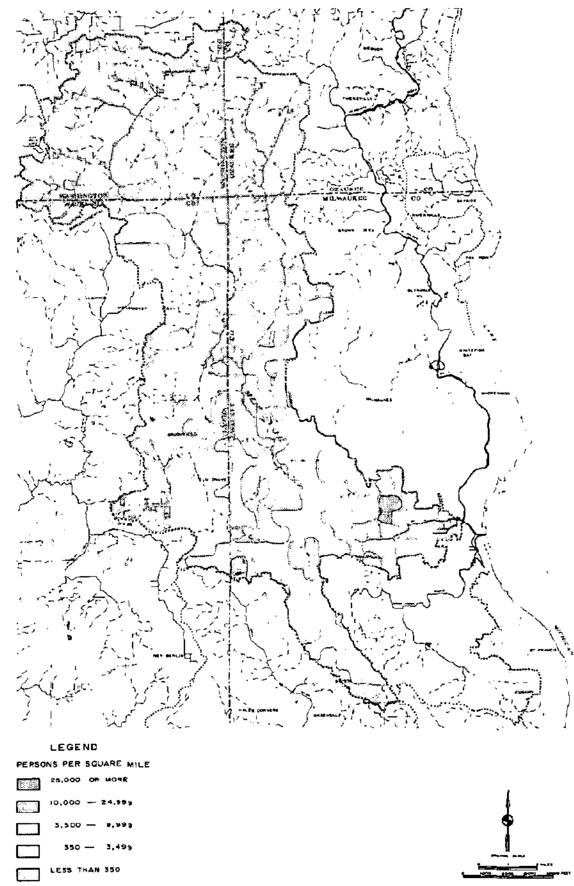
POPULATION IN THE MENOMONEE RIVER WATERSHED BY COUNTY: 1950, 1960, and 1970



Source: U. S. Bureau of the Census, and SEWRPC.

Map 5

POPULATION DENSITY IN THE MENOMONEE RIVER WATERSHED: 1970



The population of the Menomonee River watershed, estimated at about 348,000 persons in 1970, is concentrated in the lower reaches of the basin. About 80 percent of the watershed's population resides in Milwaukee County, with the remaining 20 percent found in the urbanizing areas of Ozaukee, Washington, and Waukesha Counties. During the last two decades, the average population density of the basin has increased over 40 percent, thereby further aggravating flooding, pollution, and other water resource related problems.

Source: SEWRPC.

Population Composition: The geographic distribution of the 1970 resident population of the watershed by median age is shown on Map 6. This map indicates a concentration of older people in the lower reaches of the watershed, particularly in the established urban areas within the Cities of Milwaukee, West Allis, and Wauwatosa. The median age of the population in the watershed was estimated at 27.4 years in 1970, which is just slightly lower than the median age for the Region as a whole.

Map 7 shows the 1970 geographic distribution of the average household sizes in the watershed. As in the Region, the smaller average household sizes occur in the central city and in the older first-ring suburban areas of Milwaukee County, with the larger average household sizes generally occurring outside the county and in the City of Milwaukee's northwest side. The average household size in the watershed in 1970 was 3.16 persons, with the average household size in the watershed out-

Table 4

TOTAL POPULATION AND POPULATION DENSITY OF CITIES, VILLAGES, AND TOWNS IN THE MENOMONEE RIVER WATERSHED: 1970

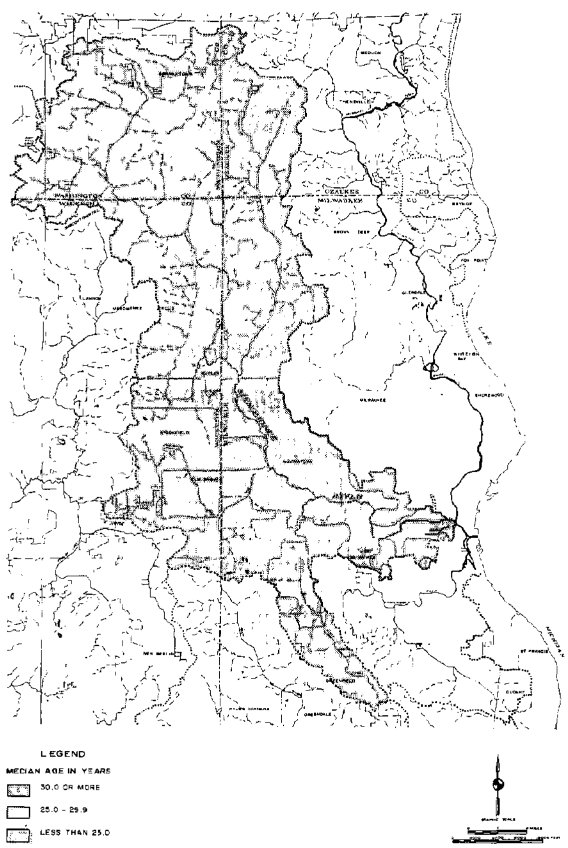
Civil Division	Population Within Watershed	Percent of Watershed Population	Area Included in Watershed (Square Miles)	Percent of Area in Watershed	Average Gross Population Density (Per Square Mile)
Cities	296,271	85.1	81.46	59.3	3,637
Villages	50,748	14.6	52.52	38.3	966
Towns	1,146	0.3	3.25	2.4	353
Total	348,165	100.0	137.23	100.0	2,537[a]

[a] *This is a 28 percent increase over the 1960 gross population density of 1,976 persons per square mile.*

Source: SEWRPC.

Map 6

DISTRIBUTION OF THE POPULATION IN THE MENOMONEE RIVER WATERSHED BY MEDIAN AGE: 1970

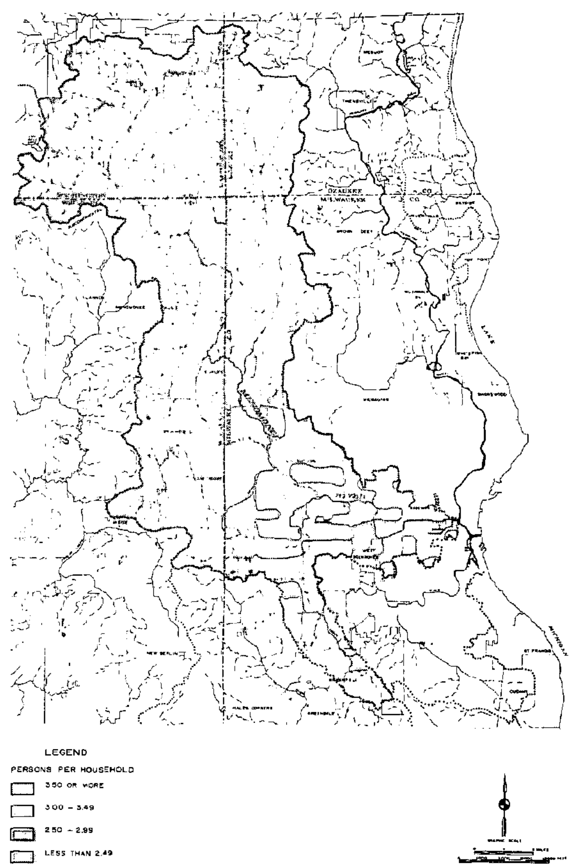


The spatial distribution of median ages within the watershed indicates that older people are concentrated in the established urban areas in the lower reaches of the basin, while younger families are evident in the more recently developed middle and upper portions of the basin. In 1970, the median age of the watershed population was estimated at 27.4 years, which is just slightly below that of the Region as a whole.

Source: SEWRPC.

Map 7

AVERAGE HOUSEHOLD SIZE IN THE MENOMONEE RIVER WATERSHED: 1970



The average household size within the Menomonee River watershed was 3.16 persons in 1970. The smaller average household sizes occur in the central city and older first-ring suburban areas of Milwaukee County, and generally correlate with areas exhibiting higher median ages. Larger households are found in the more recently developed portions of the basin inhabited by younger families, which includes the northern parts of Milwaukee County and most of Ozaukee, Washington, and Waukesha Counties.

Source: SEWRPC.

side Milwaukee County being greater than 3.50 persons per household.

Map 8 depicts the 1970 average annual household income within the watershed. The average household income within the watershed in 1970 was estimated at $10,820, slightly below that of $11,240 for the Region as a whole. As shown on Map 8, the highest average annual household incomes—over $15,000—occurred in eastern Waukesha County in the City of Brookfield and the Village of Elm Grove. The lower average annual household incomes—less than $8,000—are generally concentrated in the lower reaches of the watershed in the central part of the City of Milwaukee. Average household incomes in the remainder of the watershed ranged from $8,000 to $15,000, with higher averages in the middle and upper reaches of the watershed and lower averages generally in the lower reaches of the watershed. The age, household size, and household income data presented on Maps 6, 7, and 8 clearly indicate that the recent and current urbanization of the middle and upper portions of the watershed involves younger, larger family units with above average incomes.

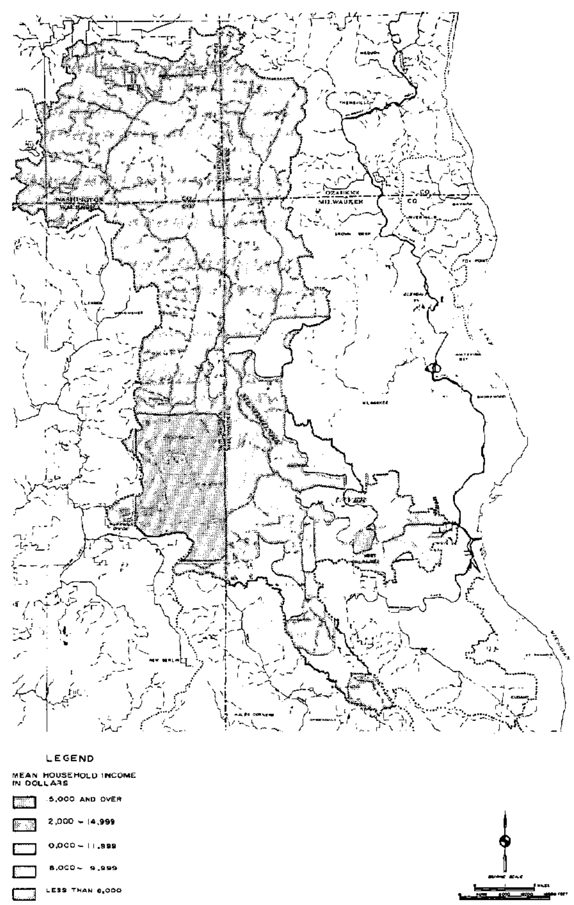
Economic Base: Increases in the population of the watershed are related to increases in the amount of economic activity within the four counties—Milwaukee, Ozaukee, Washington, and Waukesha—within which the Menomonee River watershed lies. This is true not only because population migration patterns and trends in an area are dependent upon available job opportunities, but also because jobs must ultimately be available to sustain population increases due to natural increase, and to prevent a forced out-migration of young residents initially entering the labor force. The historic growth of population in the watershed may be attributed, in part, to increasing economic activity within the four-county area within which the watershed lies.

Industrial Activity: Figure 7 shows the relative concentrations of jobs by eight major industrial groups in 1970 for Milwaukee, Ozaukee, Washington, and Waukesha Counties, and is intended to be representative of employment distribution by major industrial groups in the Menomonee River watershed. Total employment in this four-county area is highly concentrated in manufacturing, with over 35 percent of the total jobs in the manufacturing sector. The wholesale and retail trade, private service, and government service industries encompass proportionately the next largest employers within the four-county area. The relative concentration of jobs within manufacturing—the dominant industrial group—for 1970 is presented in Figure 8 for Milwaukee, Ozaukee, Washington, and Waukesha Counties. As indicated in Figure 8, the principal type of manufacturing is nonelectrical machinery, which accounts for about 28 percent of all manufacturing, while the manufacture of electrical equipment ranks second.

The largest concentration of industry within the watershed is in the City of Milwaukee, where 44 of the 69 industrial firms within the watershed employing 150 or more persons each are located. Furthermore, three

Map 8

AVERAGE ANNUAL HOUSEHOLD INCOME IN THE MENOMONEE RIVER WATERSHED: 1970



The average annual household income within the watershed in 1970 was estimated at $10,820, which was slightly below the $11,240 average for the Region. The lowest average household incomes—less than $8,000 per year—are concentrated in the central portion of the City of Milwaukee, while the highest average household incomes--in excess of $15,000 per year—occur in the Waukesha County portion of the watershed.

Source: SEWRPC.

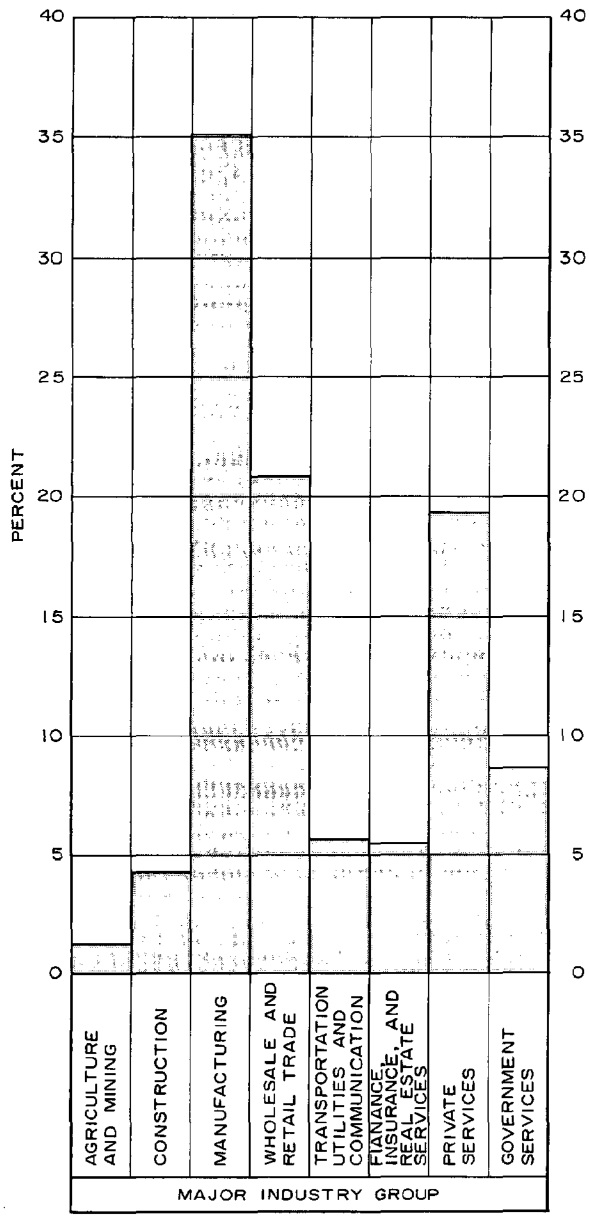
of the eight largest firms in the watershed which employ 2,000 or more persons are located in the Cities of West Allis and Wauwatosa and in the Village of West Milwaukee. Lesser employment concentrations are also found in certain outlying cities and villages within the watershed. Due to these employment concentrations, much of the working population in the watershed also resides within it. In 1970, the watershed accounted for about 20 percent of the total regional levels of population and employment opportunities.

Agricultural Activity: As of 1970, 45.1 square miles, or 33 percent of the watershed area, were being used for agricultural and related land uses, which consist of four categories: croplands and rotation pasture, orchards and nurseries, fowl and fur farms, and miscellaneous agricultural uses. A 6.9 square mile, or 13 percent, reduction in watershed land devoted to agricultural and related land uses occurred in the seven-year period from 1963 to 1970. Most of the agricultural activity in the watershed is located within the Washington and Ozaukee County portions, with secondary activity scattered over the northeast corner of Waukesha County and the northwest corner of Milwaukee County.

Although data pertaining explicitly to the agricultural economy of the Menomonee River watershed are not available, probable trends may be deduced from agricultural data for the four counties in which the watershed lies (see Table 5). Although the total number of farms in operation, the total acreage farmed, and the number of farm operators have been declining within these four counties, the average farm size, the value of farm products sold, and the average value of farm products sold per farm have been increasing. These trends are generally consistent with those observed in the nation and state. From 1964 to 1969, the number of farms and farm operators in the four counties comprising the watershed declined by over 1,000, or about 22 percent. In the same five-year period, the number of acres being farmed declined by over 77,600 acres, or 14 percent, which approximates the aforementioned 13 percent reduction in Menomonee River watershed agricultural land during

Figure 7

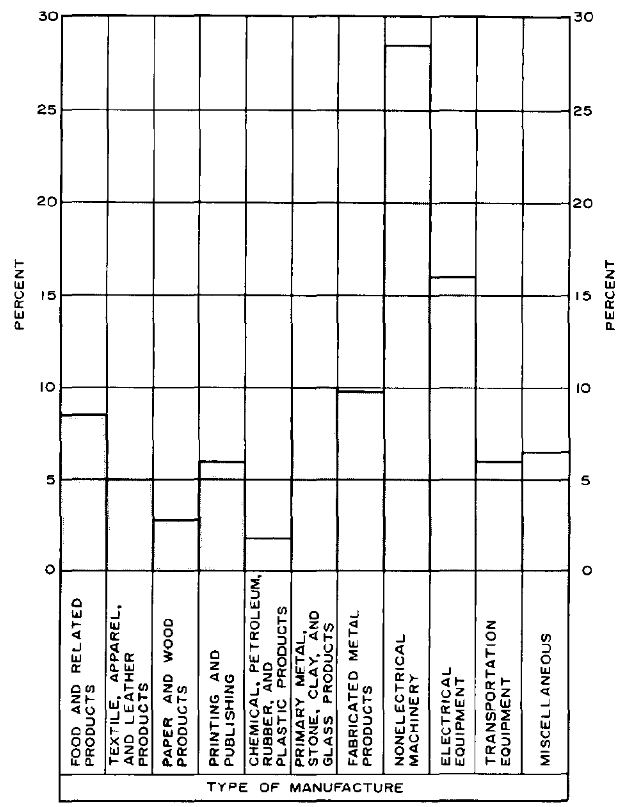
DISTRIBUTION OF TOTAL EMPLOYMENT BY MAJOR INDUSTRY GROUP FOR MILWAUKEE, OZAUKEE, WASHINGTON, AND WAUKESHA COUNTIES: 1970



Source: *U. S. Bureau of the Census, and SEWRPC.*

Figure 8

DISTRIBUTION OF MANUFACTURING EMPLOYMENT BY TYPE OF MANUFACTURING FOR MILWAUKEE, OZAUKEE, WASHINGTON, AND WAUKESHA COUNTIES: 1970



Source: *Wisconsin Department of Industry, Labor, and Human Relations, and SEWRPC.*

the 1963 to 1970 period. In contrast, from 1964 to 1969, the average farm size in the four counties comprising the watershed increased by over 11 acres, or about 10 percent; the total dollar value of all farm products sold increased by about $5 million, or 11 percent; and the average value of farm products sold per farm increased rapidly by over $4,000, or 41 percent.

With respect to the continuing importance of agriculture to the economy of the watershed, trends suggested by these data are probably somewhat optimistic. Nonquantitative but nevertheless significant indicators of the diminishing role of agriculture are evident in the headwater portions of the watershed. These indicators, which include dilapidated or poorly maintained farms, abandoned orchards, numerous real estate signs, and small, scattered residential developments, all suggest that urban development is about to significantly reduce the role of agriculture in the economy of the Menomonee River watershed.

Land Use

An important concept underlying the watershed planning effort is that an adjustment must be effected between land use development and the ability of the underlying natural resource base to sustain such development. The type, intensity, and spatial distribution of land uses determine, to a large extent, the resource demands within a watershed. Water resource demands can be correlated directly with the quantity and type of land use, as can water quality deterioration. The existing land use pattern can best be understood within the context of its historical development. Thus, attention is focused herein upon both historic and existing land use development and upon both regional and watershed, factors influencing land use.

Historical Development: The name of the watershed may be traced to its early inhabitants, the Mihneminee Indians, whose name means "wild rice." That name has gradually evolved to Menomonee, and is now applied to both the watershed and the Village of Menomonee Falls within the watershed. The historic settlement by Europeans of what is now the Southeastern Wisconsin Region had its beginning following the Indian cessions of 1829 and 1833, which transferred to the federal government all of what is now the State of Wisconsin south of the Fox River and east of the Wisconsin River. Initial urban development within the Region occurred along the Lake Michigan shoreline at the ports of Milwaukee, Port Washington, Racine, and Southport (now Kenosha), since these settlements were more directly accessible to immigration from the East Coast through the Erie Canal-Great Lakes transportation route.

The settlement of the watershed, which constituted a rich agricultural hinterland to the west and northwest, followed establishment of the port city of Milwaukee, with the pattern of historic urban land use development occurring as shown on Map 9. By 1836, the U. S. Public Land Surveys had been essentially completed in southeastern Wisconsin. In 1838, a federal land office was opened at Milwaukee, from which nearly 500,000 acres of farm land were sold at the minimum price of $1.25 per acre during the great land sale of February and March of

Table 5

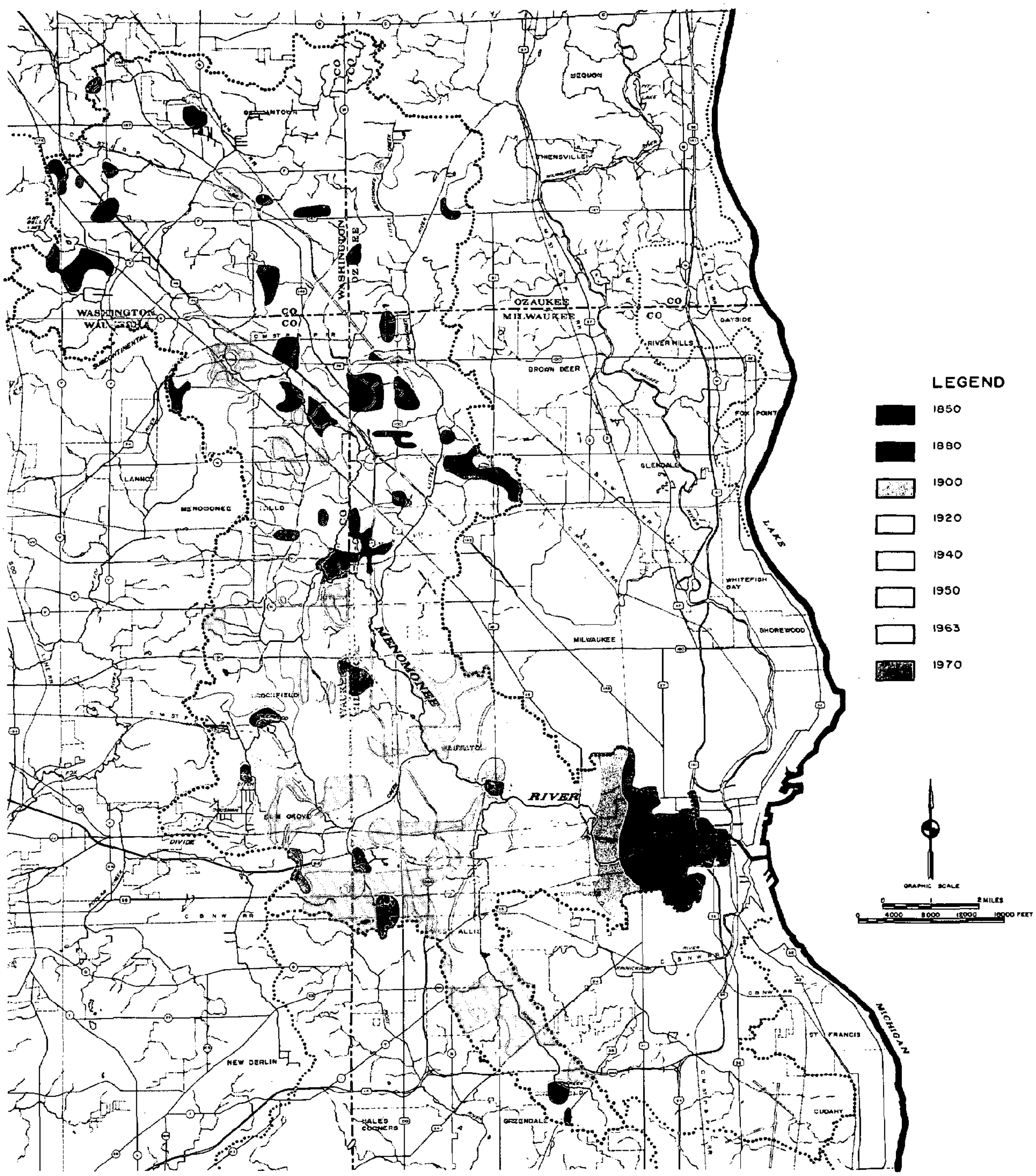
INDICATORS OF AGRICULTURAL ACTIVITY IN MILWAUKEE, OZAUKEE, WASHINGTON, AND WAUKESHA COUNTIES 1964 AND 1969

Indicator	County								Total		Average		Change 1964-1969	
	Milwaukee		Ozaukee		Washington		Waukesha							
	1964	1969	1964	1969	1964	1969	1964	1969	1964	1969	1964	1969	Absolute	Percent
Number of Farms	409	245	871	759	1,715	1,432	1,671	1,224	4,666	3,660	--	--	- 1,006	- 21.6
Acreage Farmed	25,620	17,412	108,205	105,037	211,555	186,302	208,005	167,019	553,385	475,770	--	--	- 77,615	- 14.0
Number of Farm Operators	409	245	871	759	1,715	1,432	1,671	1,224	4,666	3,660	--	--	- 1,006	- 21.6
Average Farm Size (Acres)	62.8	71.0	124.2	138.3	123.4	130.0	124.5	136.4	--	--	118.6	129.9	11.3	9.5
Value of Farm Products Sold (Thousands of Dollars)	5,292	4,423	9,263	10,932	16,010	19,959	15,332	15,541	45,897	50,855	--	--	4,958	10.8
Average Value of Farm Products Sold Per Farm (Dollars)	12,938	18,051	10,634	14,403	9,335	13,937	9,175	12,697	--	--	9,836	13,894	4,058	41.3

Source: U. S. Census of Agriculture and SEWRPC.

Map 9

HISTORICAL URBAN GROWTH IN THE MENOMONEE RIVER WATERSHED: 1850-1970



In recent decades, urbanization has been occurring at a steadily increasing rate in the watershed. More urban development has occurred since 1950 than in the entire history of the watershed prior to 1950. In the period from 1950 to 1970, a 42 percent population increase was accompanied by a 156 percent increase in urban land use, indicating a wide diffusion of urban development. As shown above, urbanization has generally occurred in a diffused pattern emanating outward from the historic urban centers into the woodlands, wetlands, and farmlands of the watershed.

Source: SEWRPC.

1839. Significantly, most of this land was not sold to speculators, but to farmers who sought the land for permanent homesteads. Most of the settlers within the watershed had been farming and living on the land with only squatter rights prior to the federal land sale.

Almost without exception the pioneer villages of the watershed were located along the Menomonee River, or on major tributaries, at natural waterfalls or rapids where small water-powered grist mills—as, for example, at Menomonee Falls—and sawmills could be built. The early settlers had to have flour, meal, feed, and lumber, so these mill sites were logical locations for the development of urban settlements.

The period from 1840 to 1860 was one of rapid settlement of the rural area of the watershed, while the villages experienced relatively little growth. Immigrants from northern Europe, Ireland, New England, and New York State settled in the watershed in increasing numbers, and occupied most of the good farmland by 1860. This was an era of enormous wheat production within the watershed, even though the crop had to be hauled long distances by wagon over extremely poor roads to markets in the ports of Milwaukee, Port Washington, and Sheboygan. Sheep raising was also important to the agricultural economy of the watershed until about 1880. Most of the wool produced was marketed at the major port cities. After 1880, both wheat and wool production declined rapidly, being supplanted by dairy farming. By 1890, as today, dairy farming was the most important agricultural industry in the watershed.

Industrial development began to occur rapidly in the watershed following the completion in 1855 of a railroad connecting the Cities of Chicago and Milwaukee. Milwaukee became the most important manufacturing center within the Region, primarily due to the immigration of skilled artisans and mechanics from Germany. Nearly all of the city's major industrial plants can trace their beginnings to the small backyard shops of these immigrants. The rapidly expanding manufacturers had their foundations in the raw materials supplied by the farms and forests of the watershed, the state, and its neighbors. Some well-known Milwaukee companies developed from small local plants within the watershed, including the Miller Brewing Company and the Falk Corporation.

During the 35-year period from 1910 to the end of World War II in 1945, the trend toward more intensive land use continued, marked particularly by the increasing mechanization of farming and the introduction of a modern, all-weather, high-speed highway system. During the approximately two decades since 1950, land use has changed more than in the entire previous 120 years. Since 1950, an affluent and mobile population has been converting land from rural to urban use for residential, commercial, institutional, and transportation purposes at an unprecedented rate. In the 20-year period extending from 1950 to 1970, a 42 percent increase in the population of the watershed was accompanied by an approximately 156 percent increase in the land devoted to urban use within the watershed. As shown on Map 9, this urbanization occurred in a diffused pattern outward from the historic urban center into the woodland and the fertile farmlands of the watershed.

A relatively large number of remnants of historic places—mills, churches, inns, public buildings, Indian villages, lime kilns—are located in and near the watershed, where, as shown on Map 10, they tend to be concentrated in the riverine areas. Table 6 contains a list of the 73 historic sites shown on Map 10, and serves to indicate the nature of each.

The concentration of historic sites along the watershed's stream system reflects the fact that there was considerable motivation for both the native Indians and the early European settlers to locate near waterways. The rivers provided water supply and a means of wastewater disposal; they were a source of power to grind grain and drive manufacturing processes; and they facilitated ready access to trade and commerce utilizing water transportation. That initial attraction to riverine areas, the early development of communities there, and the subsequent concentration of urban development in those areas are important factors contributing to current flood problems within the watershed. The comprehensive watershed planning process can serve to assist in preserving and restoring many significant historic sites, and the cultural and educational values inherent in such sites, by recommending compatible contiguous park and related open space land uses.

Existing Land Use: The general pattern of existing (1970) land use within the Menomonee River watershed is shown on Map 11, and more detailed existing land use data are presented in Tables 7 and 8. The nine land uses quantified in Table 7 are a summary of the 41 detailed land uses appearing in Table 8, the latter of which corresponds to the level of detail used in the Regional Planning Commission's 1963, 1967, and 1970 detailed regional land use inventories. Figure 9 graphically depicts the types and relative amounts of existing land uses within the Menomonee River watershed and also illustrates land use changes since 1963.

The predominantly urban characteristics of the watershed are clearly evident on Map 11 and Figure 9. Over 53 percent of the area of the watershed is currently devoted to urban, as opposed to rural, land uses. The dominant urban land use in the watershed is residential, which encompasses 34 square miles, or 25 percent of the total watershed area. Most of the larger contiguous remaining nonurbanized lands are located in the Washington and Ozaukee County portions of the watershed, with smaller parcels of rural lands remaining in the northeastern corner of Waukesha County and the northwestern corner of Milwaukee County.

The pattern of conversion from rural to urban land uses that is evident in Waukesha and Milwaukee Counties generally conforms to that recommended in the Commission's 2000 land use-transportation plan in that it is

Table 6

HISTORIC SITES IN AND NEAR THE MENOMONEE RIVER WATERSHED: 1973

Site Number[a]	Location: U. S. Public Land Survey: Township (North)	Range (East)	Section	Quarter Section[b]	Civil Division: County	City, Village, or Town	Site Name	Significant Date(s)	Significance
1	06	21	01	NE	Milwaukee	City of Milwaukee	St. Joseph's Convent Chapel	1914-17	Historic Church
2	06	21	01	SE	Milwaukee	City of Milwaukee	American System Built Houses	1916-17	Historic Home
3	·06	21	04	SW	Milwaukee	City of West Allis	West Allis Historical Museum	1887	Museum
4	06	21	26	NW	Milwaukee	City of Greenfield	Bodamer Log Cabin	1832	Museum
5	06	22	05	NE	Milwaukee	City of Milwaukee	Public Natatorium	1893-95	Historic Building
6	06	22	05	NE	Milwaukee	City of Milwaukee	St. Stanislaus Roman Catholic Church	1872-73	Historic Church
7	06	22	06	NE	Milwaukee	City of Milwaukee	R. D. Whitehead (Whitehead horse watering trough)	1910	Monument
8	06	22	06	NE	Milwaukee	City of Milwaukee	St. Jacobi Evangelical Lutheran Church	1873	Historic Church and School
9	07	20	13	SE	Waukesha	City of Brookfield	Scheibe Barn	1874	Historic Building
10	07	20	15	SE	Waukesha	City of Brookfield	Pioneer Cemetery	--	Historic Cemetery
11	07	20	15	SE	Waukesha	City of Brookfield	Brookfield Settlement Site	--	Historic Village Site
12	07	20	24	SW	Waukesha	Village of Elm Grove	Elm Grove Settlement Site	--	Historic Village Site
13	07	20	25	NE	Waukesha	Village of Elm Grove	Sisters of Notre Dame Convent	1898	Historic Church and Convent
14	07	20	27	SE	Waukesha	City of Brookfield	Dunkel Inn	1843	Historic Inn-Hotel and Early Road/Trail
15	07	21	05	NE	Milwaukee	City of Wauwatosa	Annunciation Greek Orthodox Church	1959-61	Church Architecture (Frank Lloyd Wright Design)
16	07	21	07	NE	Milwaukee	City of Wauwatosa	Butler Airport Site	1919-26	First Publicly Owned Airport in Milwaukee County
17	07	21	17	NE	Milwaukee	City of Milwaukee	Mount Mary College	1928	Historic School and Church
18	07	21	21	NE	Milwaukee	City of Wauwatosa	Price Davis House	1854	Historic Home
19	07	21	21	NE	Milwaukee	City of Wauwatosa	Lowell Damon House	1844-46	Historic Home and Museum
20	07	21	22	SW	Milwaukee	City of Wauwatosa	Harts Hill Marker	--	Monument
21	07	21	25	NE	Milwaukee	City of Milwaukee	Fred Pabst, Jr. House	1897-98	Historic Home
22	07	21	25	NE	Milwaukee	City of Milwaukee	Second Church of Christ Scientist	1913	Historic Church
23	07	21	25	NE	Milwaukee	City of Milwaukee	Tripoli Temple	1928	Masonic Temple
24	07	21	25	NW	Milwaukee	City of Milwaukee	Miller Brewing Co.	1855	Museum
25	07	21	25	NW	Milwaukee	City of Milwaukee	Watertown Plank Road Marker	1848-53	Early Road/Trail
26	07	21	33	SE	Milwaukee	City of West Allis	State Fair Park	1891	Festival Site and Indian Mounds
27	07	21	34	SW	Milwaukee	City of West Allis	Allis-Chalmers Corporation	1847	Historic Mill, Factory
28	07	21	35	NW	Milwaukee	City of Milwaukee	National Soldiers Home	1867	Museum
29	07	22	19	SW	Milwaukee	City of Milwaukee	St. Michael's Roman Catholic Church	1891-93	Historic Church
30	07	22	19	SE	Milwaukee	City of Milwaukee	Robert Machek House	1893-1907	Historic Home
31	07	22	29	NW	Milwaukee	City of Milwaukee	Monuments in the Court of Honor	--	Monuments
32	07	22	29	NW	Milwaukee	City of Milwaukee	Milwaukee County Courthouse	1929-31	Government Building
33	07	22	29	NW	Milwaukee	City of Milwaukee	Trinity Evangelical Lutheran Church	1878-80	Historic Church
34	07	22	29	NW	Milwaukee	City of Milwaukee	Tower Clock	1905	Historic Clock
35	07	22	29	NW	Milwaukee	City of Milwaukee	Mitchell House	1850	Historic Home
36	07	22	29	NW	Milwaukee	City of Milwaukee	Milwaukee Public Museum	1960-71	Museum
37	07	22	29	NW	Milwaukee	City of Milwaukee	Pabst Brewing Co. Complex	1872	Historic Buildings/Brewery
38	07	22	29	NW	Milwaukee	City of Milwaukee	St. Benedict The Moor Roman Catholic Church	1923	Historic Church
39	07	22	29	NW	Milwaukee	City of Milwaukee	Milwaukee Public Library and Museum	1895-99	Library and Museum
40	07	22	29	SW	Milwaukee	City of Milwaukee	Calvary Presbyterian Church	1870-72	Historic Church
41	07	22	29	SW	Milwaukee	City of Milwaukee	Gesu Roman Catholic Church	1893-94	Historic Church
42	07	22	29	SW	Milwaukee	City of Milwaukee	St. James' Episcopal Church	1867-70	Historic Church
43	07	22	30	NE	Milwaukee	City of Milwaukee	18th Street School	1876	Historic School
44	07	22	30	NE	Milwaukee	City of Milwaukee	Mt. Sinai Neighborhood	--	Historic Buildings
45	07	22	30	NW	Milwaukee	City of Milwaukee	Munkwitz Apartments	1916-17	Historic Home
46	07	22	30	NW	Milwaukee	City of Milwaukee	Frederick Pabst Mansion	1890-92	Historic Home
47	07	22	30	SE	Milwaukee	City of Milwaukee	Marquette University	1857	Historic School
48	07	22	31	NW	Milwaukee	City of Milwaukee	Mitchell Park Horticultural Conservatory	1930 and 1959-67	Architecture and Monument
49	07	22	32	NE	Milwaukee	City of Milwaukee	Holy Trinity-Our Lady of Guadalupe Roman Catholic Church	1849-50	Historic Church and School

Table 6 (continued)

Site Number[a]	Location						Site Name	Significant Date(s)	Significance
	U. S. Public Land Survey				Civil Division				
	Township (North)	Range (East)	Section	Quarter Section[b]	County	City, Village, or Town			
50	07	22	32	NE	Milwaukee	City of Milwaukee	George Ziegler Candy Co. Building	1907	Historic Building
51	07	22	32	SW	Milwaukee	City of Milwaukee	St. Michael's Ukranian Catholic Church	1874	Historic Church
52	07	22	32	SW	Milwaukee	City of Milwaukee	St. Patrick's Roman Catholic Church	1893-95	Historic Church
53	07	22	32	SE	Milwaukee	City of Milwaukee	Clinton Street Filling Station	1930	Historic Gas Station
54	08	20	03	NE	Waukesha	Village of Menomonee Falls	Miller-Davidson House	1858	Historic Farm and Museum
55	08	20	03	SW	Waukesha	Village of Menomonee Falls	Menomonee Falls Settlement Site	1851	Historic Village and Dam Site
56	08	20	03	SW	Waukesha	Village of Menomonee Falls	George Rowell Home	- -	Historic Home
57	08	20	09	NW	Waukesha	Village of Menomonee Falls	Watershed Divide Site	- -	Monument
58	08	20	10	NE	Waukesha	Village of Menomonee Falls	Lime Kiln Park	1890	Lime Kiln Monument
59	08	20	13	SW	Waukesha	Village of Menomonee Falls	St. Anthony's Roman Catholic Church	1865	Historic Church and Cemetery
60	08	20	13	SW	Waukesha	Village of Menomonee Falls	Fussville Settlement Site	1890s	Historic Village Site
61	08	21	19	NE	Milwaukee	City of Milwaukee	West Granville Presbyterian Church	1860-61	Historic Church
62	09	19	12	SW	Washington	Town of Richfield	Laubenheimer Family Cemetery	1842	Historic Cemetery
63	09	19	35	SE	Washington	Town of Richfield	Colgate Settlement Site	- -	Historic Village Site
64	09	20	08	SE	Washington	Village of Germantown	Evangelical Christus Kirche	1861	Pioneer Church and Cemetery
65	09	20	09	SE	Washington	Village of Germantown	Rockfield Lime Kiln Ruins	1854	Lime Kilns
66	09	20	17	NE	Washington	Village of Germantown	Old Germantown Mutual Fire Insurance Building	1870	Historic Building
67	09	20	22	NE	Washington	Village of Germantown	Germantown Mutual Insurance Co. Building	1854	Historic Building
68	09	20	35	SE	Washington	Village of Germantown	Old Germantown Township Site	1939	Historic Settlement Site
69	09	21	08	SE	Ozaukee	City of Mequon	Wilde House	1869	Historic Home
70	09	21	18	SE	Ozaukee	City of Mequon	Schneider Home	- -	Historic Home
71	09	21	19	NE	Ozaukee	City of Mequon	Trinity Evangelical Lutheran Church	1839	Historic Church and Village Site
72	09	21	19	NE	Ozaukee	City of Mequon	Dalman House	- -	Historic Home
73	09	21	30	NE	Ozaukee	City of Mequon	Hilgendorf Farm	1842	Historic Home and Farm

[a] *See Map 10.*

[b] *Quarter sections are numbered 1 through 4 beginning in the northeast quarter and proceeding in a counterclockwise direction.*

Source: SEWRPC.

emanating outward from existing urban development into areas recommended for urban use. In contrast, urbanization of the Washington and Ozaukee County segments of the watershed is occurring in the form of small clusters of residential development scattered over lands recommended for agricultural use or for preservation as primary environmental corridors, in conflict with recommendations contained in the Commission's adopted regional land use plan.

As illustrated on Map 11, a significant amount of public recreational and open space land exists within the Milwaukee County portion of the watershed, consisting primarily of the Milwaukee County park system. Milwaukee County parklands encompass 6.1 square miles, or about 11 percent, of the Milwaukee County portion of the Menomonee River watershed. In contrast, the Waukesha, Washington, and Ozaukee portions of the watershed contain little or no public recreational and open space lands.

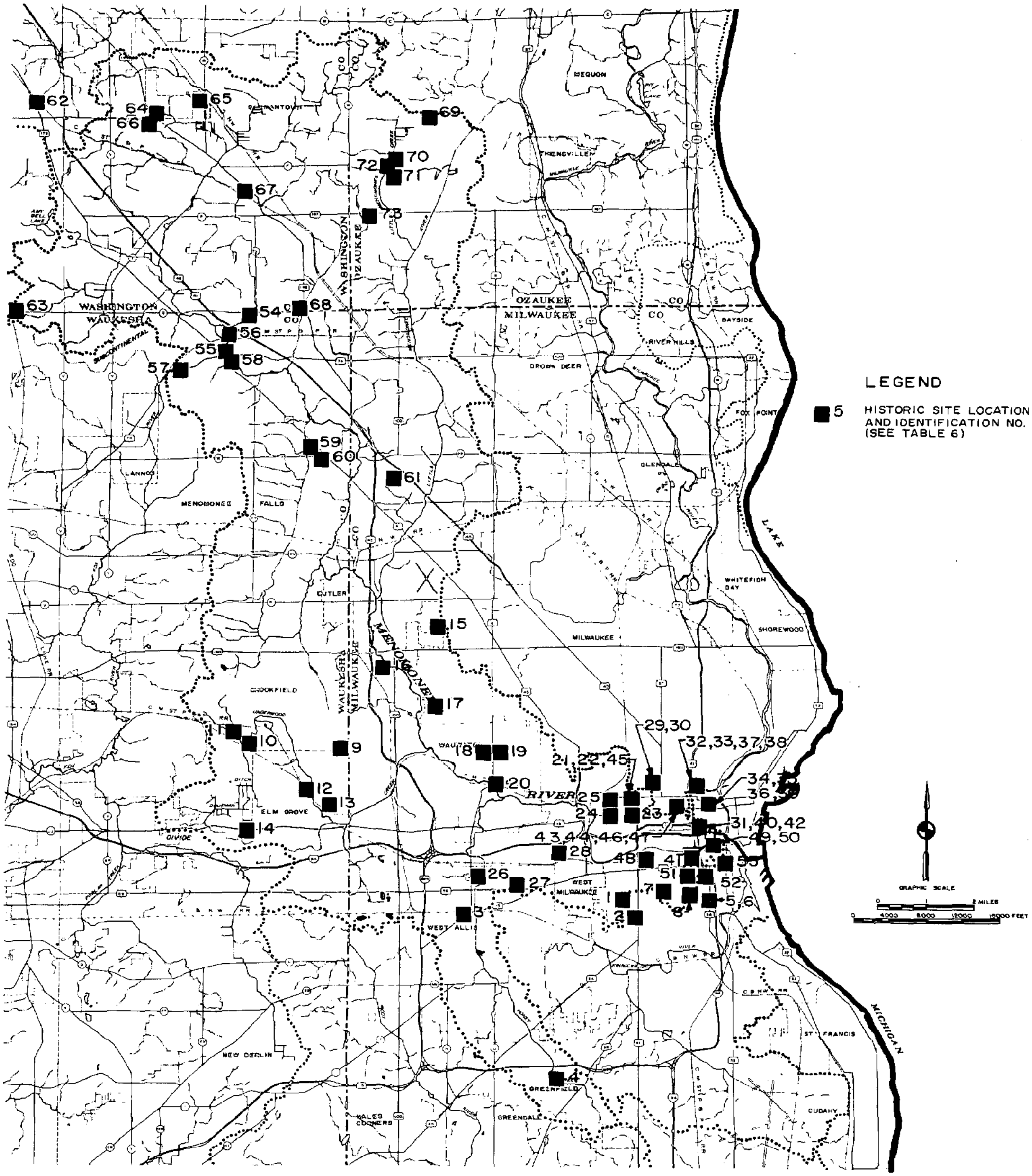
About nine square miles, or an additional 7 percent of the area of the watershed, were converted from rural to urban land uses during the seven-year period from 1963 to 1970, as shown in Table 7 and Figure 9. About 3 percent of the area of the seven-county planning region was changed from rural to urban land uses during that same seven-year period. Therefore, the Menomonee River watershed experienced an urbanization rate significantly greater than that exhibited by the Region as a whole.

Public Utility Base

Sanitary Sewer Service: The construction of public sanitary sewerage facilities has not fully kept pace with the rapid urbanization of the watershed, with the

Map 10

HISTORIC SITES IN AND NEAR THE MENOMONEE RIVER WATERSHED: 1973

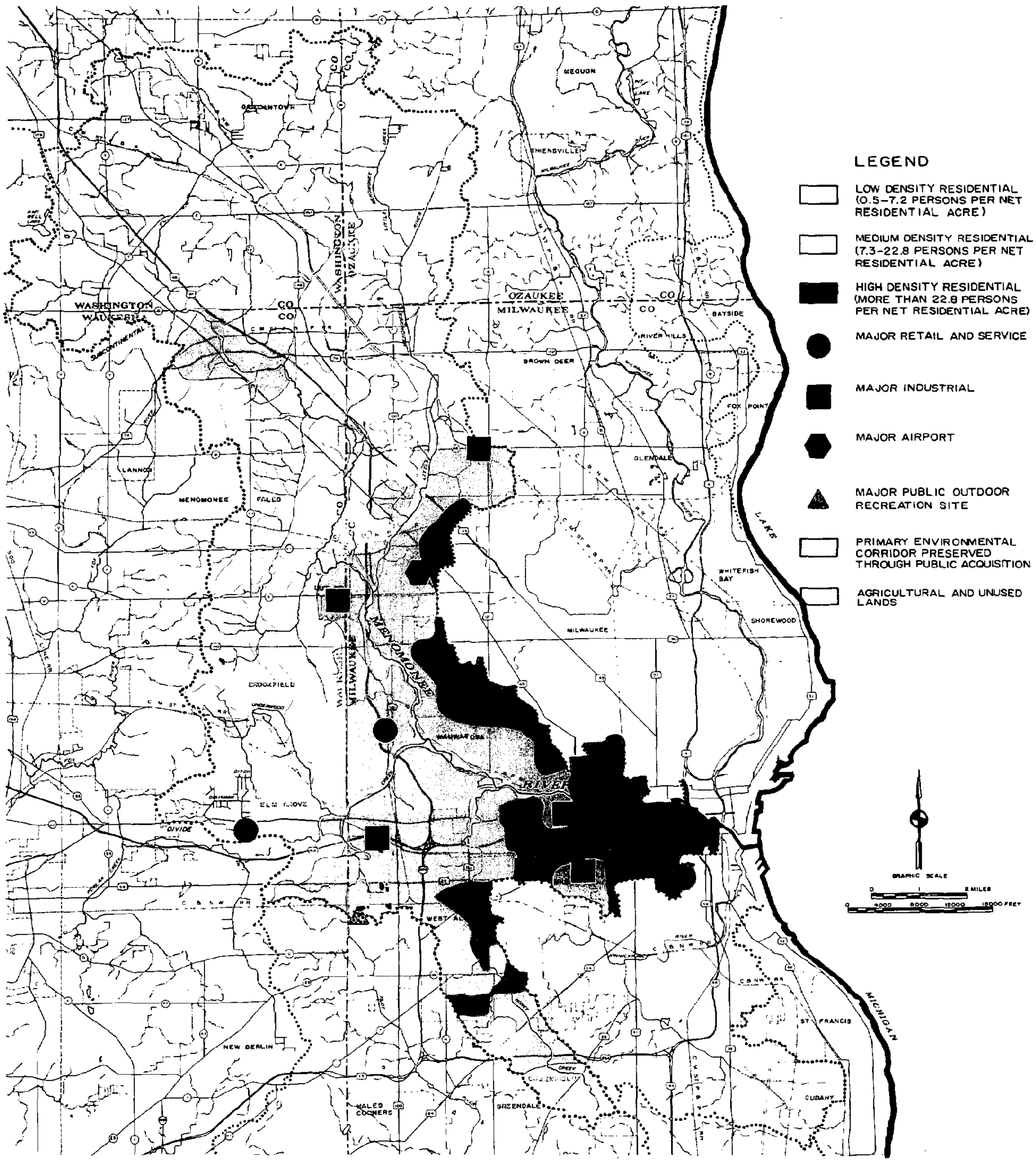


A relatively large number of remnants of historic places, such as mills, inns, churches, public buildings, Indian villages, and lime kilns, are located within the watershed. Remnants of these historic sites tend to be concentrated along the watershed's stream system, reflecting the considerable motivation for both native Indian and early European settlers to locate near waterways. This initial attraction to riverine areas, the early development of communities there, and the subsequent concentration of urban development in those areas are important factors contributing to current flood problems in the watershed. Preservation of the best remaining historic sites and structures should be given careful consideration in the planning for, and development of, the watershed.

Source: SEWRPC.

Map 11

GENERALIZED EXISTING LAND USE IN THE MENOMONEE RIVER WATERSHED: 1970



As of 1970, more than 53 percent of the area of the Menomonee River watershed was devoted to urban land uses. The dominant urban land use in the basin is residential, which encompasses 25 percent of the watershed area. The overall spatial distribution of land use in the watershed is characterized by rural land use and scattered low density residential areas in the headwater areas, contiguous low and medium density land uses in the middle portions of the basin, and high density residential land uses and industrial, retail, and service activities in the lower segments of the basin.

Source: SEWRPC.

Table 7

URBAN AND RURAL LAND USE IN THE MENOMONEE RIVER WATERSHED: 1963 AND 1970

Land Use Category	1963 Area (Square Miles)	1963 Percent of Watershed	1963 Percent of Major Category	1970 Area (Square Miles)	1970 Percent of Watershed	1970 Percent of Major Category
Urban						
Residential	30.32	22.35	47.65	33.89	24.99	46.64
Retail and Service	1.54	1.14	2.42	1.77	1.31	2.44
Wholesale and Storage	1.08	0.80	1.70	1.55	1.14	2.13
Manufacturing	2.22	1.64	3.49	2.27	1.67	3.12
Transportation, Communication, and Utility Facilities	19.67	14.50	30.91	22.21	16.38	30.56
Governmental and Institutional	4.12	3.04	6.47	5.02	3.70	6.91
Park and Recreation	4.68	3.45	7.36	5.96	4.39	8.20
Subtotal	63.63	46.92	100.00	72.67	53.58	100.00
Rural						
Agriculture and Agriculture Related	52.00	38.33	72.22	45.11	33.26	71.65
Other Open Lands, Swamps, and Water Areas	20.00	14.75	27.78	17.85	13.16	28.35
Subtotal	72.00	53.08	100.00	62.96	46.42	100.00
Total	135.63[a]	100.00	--	135.63[a]	100.00	--

[a] *This figure represents the total area of the watershed as determined by approximating the watershed boundary by U. S. Public Land Survey quarter section and summing the quarter section totals. The actual measured watershed total is 137.23 square miles, or 87,827 acres, representing a difference of 1.60 square miles, or about 1,025 acres, from the approximated watershed total.*

Source: SEWRPC.

result that some suburban development is presently still dependent upon individual septic tank sewage disposal systems. Significant concentrations of unsewered urban development within the watershed—areas dependent on individual septic tank sewage disposal systems—are evident on Map 12. Such areas are located throughout the City of Brookfield and the Village of Menomonee Falls. Smaller clusters of unsewered urban development exist in the City of Mequon, and at several small sites scattered throughout the Village of Germantown.

About 61 square miles, or 84 percent of the urbanized area of the watershed and 45 percent of the total watershed area, and approximately 311,500 people, or about 89 percent of the total watershed population, were served by public sanitary sewerage facilities in 1970. The existing public sanitary sewer service areas within the watershed are shown on Map 12, together with the locations of the four remaining municipal sewage treatment plants within the watershed.[1] Detailed information on the treatment provided by these plants is presented in Chapter VII of this report.

Of special significance is the fact that almost all of the proposed sanitary sewerage service within the watershed and outside of Milwaukee County is included in the planned service area of the Metropolitan Sewerage District of the County of Milwaukee (see Maps 4 and 12). Within this service area, comprising about 102 square miles, or nearly 75 percent of the total watershed area, sanitary sewage will be collected and transmitted to plants located directly on the shore of Lake Michigan for treatment and disposal. A very small—less than one square mile—unsewered portion of the City and Town of Brookfield in the Menomonee River watershed is in the planned sewer service area of the City of Brookfield sewage treatment plant.

Water Supply Service: Public water supply systems serve a somewhat smaller proportion of the watershed area than do public sanitary sewerage systems. As in the case of public sanitary sewerage systems, public water supply system expansion has not kept pace with urban development, and as a result much suburban development relies

[1] *There were five municipal sewage treatment plants located in the watershed at the initiation of the Menomonee River watershed planning program in 1972. One of these, the Village of Germantown sewage treatment plant located on the south side of the village, was permanently removed from service on November 2, 1973, upon completion of a force main from that site to the northern sewage treatment plant.*

on private wells. The largest concentrations of urban development not served by public water supply systems are located in the City of Brookfield and the Villages of Elm Grove and Menomonee Falls. Smaller areas of urban development not served by public water supply systems are located in the Cities of New Berlin and Mequon and in the Village of Germantown.

In 1970, about 56 square miles, or 77 percent of the urbanized area of the watershed, 41 percent of the total watershed area, and 85 percent of the total watershed population, were served by public water supply systems. The existing service areas of the eight public water supply systems in the watershed and of the five privately operated water systems are shown on Map 13.

Three of the publicly owned and operated water supply systems in the watershed—the Village of Greendale Water and Sewer Utility and the Wauwatosa and West Allis utilities—all purchase water wholesale from a fourth such system, the Milwaukee Water Works. The remaining four public water supply systems and all the privately operated water systems, as well as individual supply systems, depend entirely upon groundwater resources.

It is of interest to note that all of the four public water utilities located in the Milwaukee County portion of the watershed utilize Lake Michigan as a source, whereas all of the four public utilities in the Waukesha and Washington County parts of the watershed draw on the groundwater reservoir. There are no public or private water utilities presently operating in the Ozaukee County portion of the watershed.

Electric Power Service: An adequate supply of electric power is available to all portions of the watershed, such power being supplied by the Wisconsin Electric Power Company which is authorized to operate throughout the Menomonee River watershed. Residential service is available anywhere within the watershed, and low-voltage lines are in place along nearly every rural highway. Electric power adequate to meet any commercial or industrial need could and would, as a matter of established utility corporation policy, be expanded to any customer requesting electric service, with the sole limitation being that the anticipated earnings from a particular customer must, over a four-year period, be equal to, or greater than, the cost of extending such service.

Gas Service: Natural gas is available to all portions of the watershed. As a matter of established utility corporation policy, any major natural gas customer can obtain gas service anywhere within the franchise portions of the watershed, but extensions to serve small potential customers in areas remote from existing gas mains must be deferred until the number of such customers economically justifies the necessary extension. The Wisconsin Gas Company provides service to the Milwaukee, Ozaukee, and Washington County portions of the watershed, and to the Village of Menomonee Falls, the eastern half of the City of Brookfield, and the Village of Elm Grove in Waukesha County. The Wisconsin Natural Gas Company serves the remaining small portions of the watershed in Waukesha County.

Transportation

Highways: As shown on Map 14, the Menomonee River watershed, like the Region of which it is an integral part, is very well served by an extensive all-weather, high-speed highway system, including 35.4 lineal miles of freeway. Most of the arterial highways presently carrying traffic volumes exceeding 4,000 vehicles per average weekday are either major intercity and interregional routes through the watershed or routes that radiate from the Milwaukee urbanized area. The extensive highway system in general, and the freeway system in particular, facilitate rapid movement by automobile between the lower industrial-commercial-business centers of the watershed and the upper urban and urbanizing areas. The extensive highway system has influenced the spatial location of urban development in the watershed, which has also been influenced, to a lesser extent, by the location of natural resources such as streams, woodlands, wetlands, and fertile farmland. Partly because of that highway system, strong urbanization pressures may be expected to be exerted on the remaining rural headwater areas of the watershed, which are located within a 30-minute driving time of lower watershed centers of employment, shopping, and service.

Motor vehicle exhaust is a major source of air pollutants such as carbon monoxide, hydrocarbons, and nitrogen oxides, and in addition, motor vehicle movements are a source of particulate matter, which also constitutes an air pollutant. Depending on concentration in the atmosphere, these pollutants may be damaging to property, harmful to flora and fauna, and harmful to human health. Such pollutants can also be washed out of the atmosphere and off of surfaces on which deposited, and thus become water pollutants. As a result of growing concern over the potential impact of motor vehicles on air quality in southeastern Wisconsin, the Commission, in cooperation with the Wisconsin Department of Natural Resources and the Wisconsin Department of Transportation, has undertaken an Air Quality Maintenance Planning Program for southeastern Wisconsin. The Prospectus for the Air Quality Maintenance Planning Program was approved by the Commission in July 1974, and the maintenance plan is scheduled for completion during 1976. The air quality maintenance plan will include an inventory of line sources of air pollutants—which include highways—as well as area and point sources, to be followed by the preparation of forecasts of future ambient air quality conditions. These forecast conditions will be compared to the established air quality standards, and air quality management strategies developed for resolving deficiencies. The recommended strategies may include elements specifically related to the highway system in the Menomonee River watershed.

The highway system serving the watershed is also important to the watershed planning program because of associated potential adverse affects on surface water quality. For example, as discussed in Chapter VII of this report, winter highway maintenance activities, particularly deicing, may be expected to have detectable and possibly harmful effects on the rivers and streams of the watershed.

Table 8

DETAILED URBAN AND RURAL LAND USE IN THE MENOMONEE RIVER WATERSHED: 1970

Land Use Category	Area (Square Miles)	Percent of Watershed[a]
Urban		
Residential		
Single-Family	27.70	20.42
Two-Family	1.73	1.28
Multifamily High Rise	0.04	0.03
Multifamily Low Rise	1.17	0.86
Mobile Homes	0.07	0.05
Residential Under Development	3.18	2.34
Retail and Service		
Local Retail and Service	1.71	1.26
Regional Retail and Service	0.06	0.04
Wholesale and Storage		
Wholesale (Open)	0.85	0.63
Wholesale (Enclosed)	0.70	0.52
Manufacturing		
Manufacturing (All Kinds)	1.53	1.13
Extractive (Quarries, Mining)	0.74	0.55
Transportation, Communication, and Utility Facilities		
Rail, Bus, and Ship Terminals	0.08	0.06
Railroad Right-of-Way	1.31	0.97
Railroad Yards	0.64	0.47
Airports (Terminal and Field)	0.59	0.44
Local and Collector Street Right-of-Way	9.06	6.68
Arterial Street and Highway Right-of-Way	4.37	3.22
Freeway and Expressway Right-of-Way	2.38	1.75
Truck Terminals	0.26	0.19
Off-Street Parking	2.43	1.79
Communication and Utility Facilities (No Offices)	1.09	0.80
Governmental and Institutional		
Local Institution	1.27	0.94
Regional Institution	3.56	2.62
Local Government	0.13	0.10
Regional Government	0.06	0.04
Park and Recreation		
Local Public Recreation Area (Enclosed)	0.01	0.01
Local Public Recreation Area (Open)	3.53	2.60
Regional Public Recreation Area (Enclosed)	--	--
Regional Public Recreation Area (Open)	0.51	0.38
Private and Other Recreation Areas (Natural Intensive Use)	0.03	0.02
Private and Other Recreation Areas (Artificial Intensive Use)	1.88	1.39
Subtotal	72.67	53.58

Table 8 (continued)

Land Use Category	Area (Square Miles)	Percent of Watershed[a]
Rural		
Agriculture and Agriculture Related		
Crop Lands and Rotation Pasture	44.51	32.82
Orchards and Nurseries	0.53	0.39
Fowl and Fur Farms	0.03	0.02
Other Agricultural Uses	0.04	0.03
Other Open Lands, Swamps, and Water Areas		
Lakes, Rivers, Streams, and Canals[b]	0.56	0.41
Swamps, Marshes, and Wetlands[b]	3.85	2.84
Unused Lands	7.11	5.24
Landfill and Dumps	0.39	0.29
Woodlands[b]	5.94	4.38
Subtotal	62.96	46.42
Total	135.63[c]	100.00

[a]*Percent of watershed was calculated by dividing the area (in square miles) by 135.63.*

[b]*The wetland and woodland area data presented in this table were determined through air photo interpretation, delineation, and measurement by SEWRPC as part of the watershed land use inventory, and as such, are not strictly comparable to the wetland and woodland area data presented as part of the natural resource inventory in Chapter IX of this volume.*

[c]*This figure represents the total area of the watershed as determined through approximating the watershed boundary by U. S. Public Land Survey quarter section and summing the quarter section totals. The actual measured watershed total is 137.23 square miles, or 87,827.20 acres, representing a difference of 1.60 square miles, or about 1,025 acres, from the approximated watershed total.*

Source: SEWRPC.

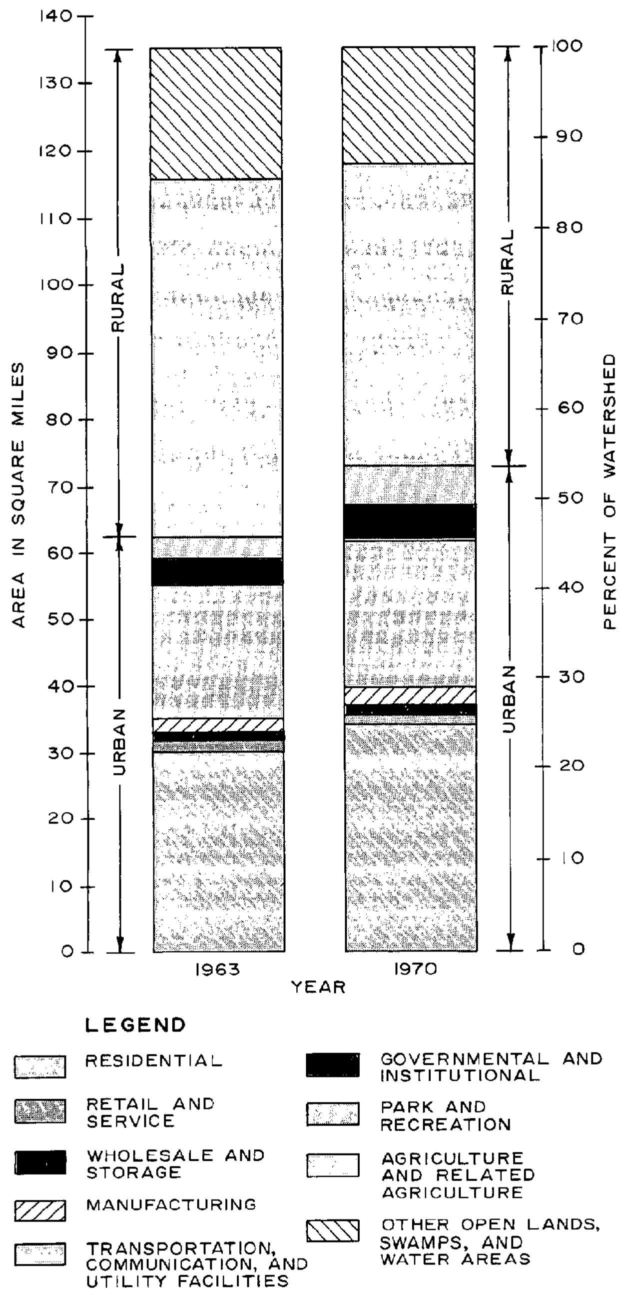
Bus Service: The transportation needs of the population, determined in large part by the distribution of residential development in relation to centers of employment, shopping, and other activities, together with the configuration of this highway system of the watershed, have resulted in the development of three types of bus service: urban mass transit, intercity bus service, and suburban mass transit. Urban mass transit service within the watershed is provided by the Milwaukee and Suburban Transport Corporation, which provides service to that intensely urbanized portion of the watershed within Milwaukee County lying south of W. Silver Spring Drive, or approximately 30 percent of the watershed area. An important feature of urban mass transit service in the watershed is the express commuter service, known as "Freeway Flyer" service, provided between the Milwaukee central business district and the following three terminal areas located in suburban areas of the watershed: the Treasure Island terminal area located in the City of Brookfield at N. 125th Street and W. Capitol Drive, the Mayfair Mall terminal area located in the City of Wauwatosa at N. 105th Street and W. North Avenue, and the Spring Mall terminal area located in the City of Greenfield at S. 76th Street and W. Coldspring Road. This high-speed, nonstop bus service is provided via the existing freeway system, reducing the need for commuting residents of the watershed to drive private automobiles into the central areas of Milwaukee County.

Intercity bus service is provided by Greyhound Lines-West, which operates a route connecting the central business district of Milwaukee, the Village of Menomonee Falls, and points to the northwest, and by Wisconsin Coach Lines, Inc., which provides service between the central business district of Milwaukee and points north and west such as Menomonee Falls, Wauwatosa, Brookfield, and West Allis. Although operated primarily as intercity routes, some of the Wisconsin Coach Lines runs may be considered to provide suburban mass transit service as well.

Railroad Service: Railroad service in the watershed is limited to freight hauling, except for scheduled Amtrak passenger service over the lines of the Chicago, Milwaukee, St. Paul and Pacific Railroad Company (Milwaukee Road) between the Union Station in Milwaukee, which is the only stop in the watershed, and Chicago to the south and Minneapolis-St. Paul to the west. The Milwaukee Union Station provides the only rail passenger terminal within four of the Region's seven counties.

Figure 9

DISTRIBUTION OF URBAN AND RURAL LAND USE IN THE MENOMONEE RIVER WATERSHED: 1963 and 1970



Source: SEWRPC.

The Chicago, Milwaukee, St. Paul and Pacific Railroad formerly operated an intraregional commuter train between the Milwaukee central business district and the City of Watertown in Jefferson County. This train, popularly known as the "Cannonball," operated daily with one trip in each direction and made stops within the watershed in the City of Brookfield, the Village of Elm Grove, and the City of Wauwatosa. The Wisconsin Public Service Commission granted the railroad permission to discontinue the train in July 1972, and the Cannonball's last run was made July 31, 1972.

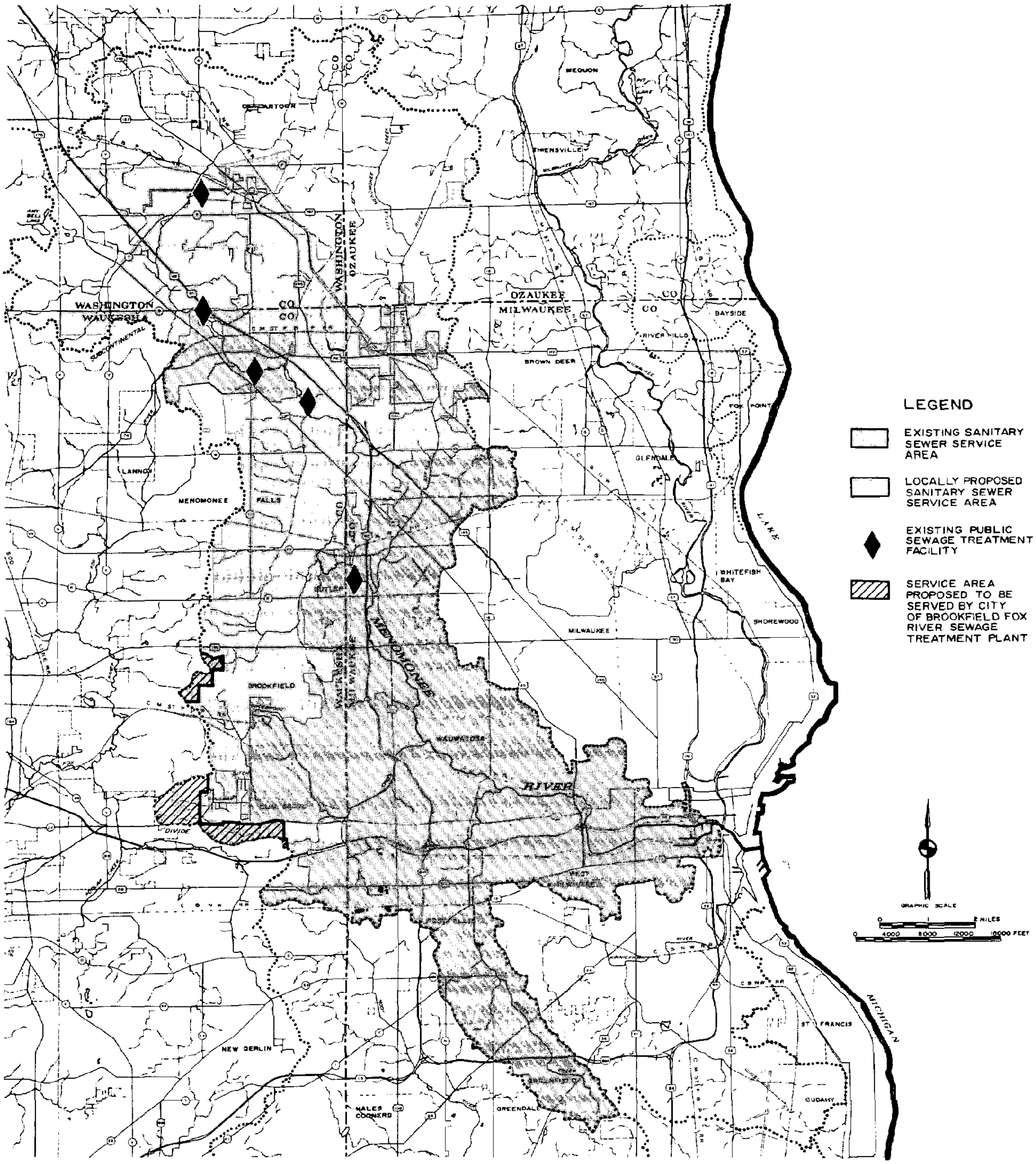
Extensive freight service is provided throughout the watershed by the Milwaukee Road and the Chicago and Northwestern Railroad. As shown on Map 14, railroad lines are concentrated in the "industrial valley" of the watershed, from which location lines radiate to the west and north, thereby traversing most of the watershed. Both of these railroads traverse the remaining rural headwater areas of the watershed. The potential to provide freight service to these areas and thereby support new commercial and industrial activity may contribute to urbanization pressures in the watershed headwaters.

Two of the largest Milwaukee metropolitan area railroad classification yards are located within the Menomonee River watershed. The Milwaukee Road maintains a large classification yard and maintenance complex in the City of Milwaukee in the Menomonee industrial valley, while the Chicago and Northwestern has its "Butler" classification yard located immediately east of the Village of Butler in the Cities of Milwaukee and Wauwatosa. In addition to their important role as integral parts of the watershed's surface transportation system and commercial and industrial activity, these large railroad yards may have adverse effects on surface water quality, inasmuch as both are located very close to the Menomonee River, and therefore may be a potential source of pollution.

Commercial Shipping: The main channel of the Menomonee River is navigable by large commercial vessels from its junction with the Milwaukee River to approximately N. 25th Street in the City of Milwaukee. The estuary portion of the river forms a relatively complex system of canals and slips serving the Menomonee Valley industrial area, including the South Menomonee Canal and the Burnham Canal (see Map 2). The river and its estuary thus constitute important components of the Great Lakes-St. Lawrence Seaway transportation system and of the international Port of Milwaukee. Bulk materials such as coal, sand, stone, cement, and scrap metals have traditionally been the primary cargoes handled in the Menomonee River watershed portion of the port. The large amount of commercial shipping activity within the estuary portion of the watershed, coupled with that in the remainder of the Port of Milwaukee, may be expected to have important economic and water quality impacts in the estuary and Lake Michigan shoreline areas. As indicated in Chapter I, however, the estuary portion of the Menomonee River watershed—and thus the economic and water quality impact of the commercial shipping activity found there—was excluded from the Menomonee

Map 12

PUBLIC SANITARY SEWER SERVICE AREAS IN THE MENOMONEE RIVER WATERSHED: 1970

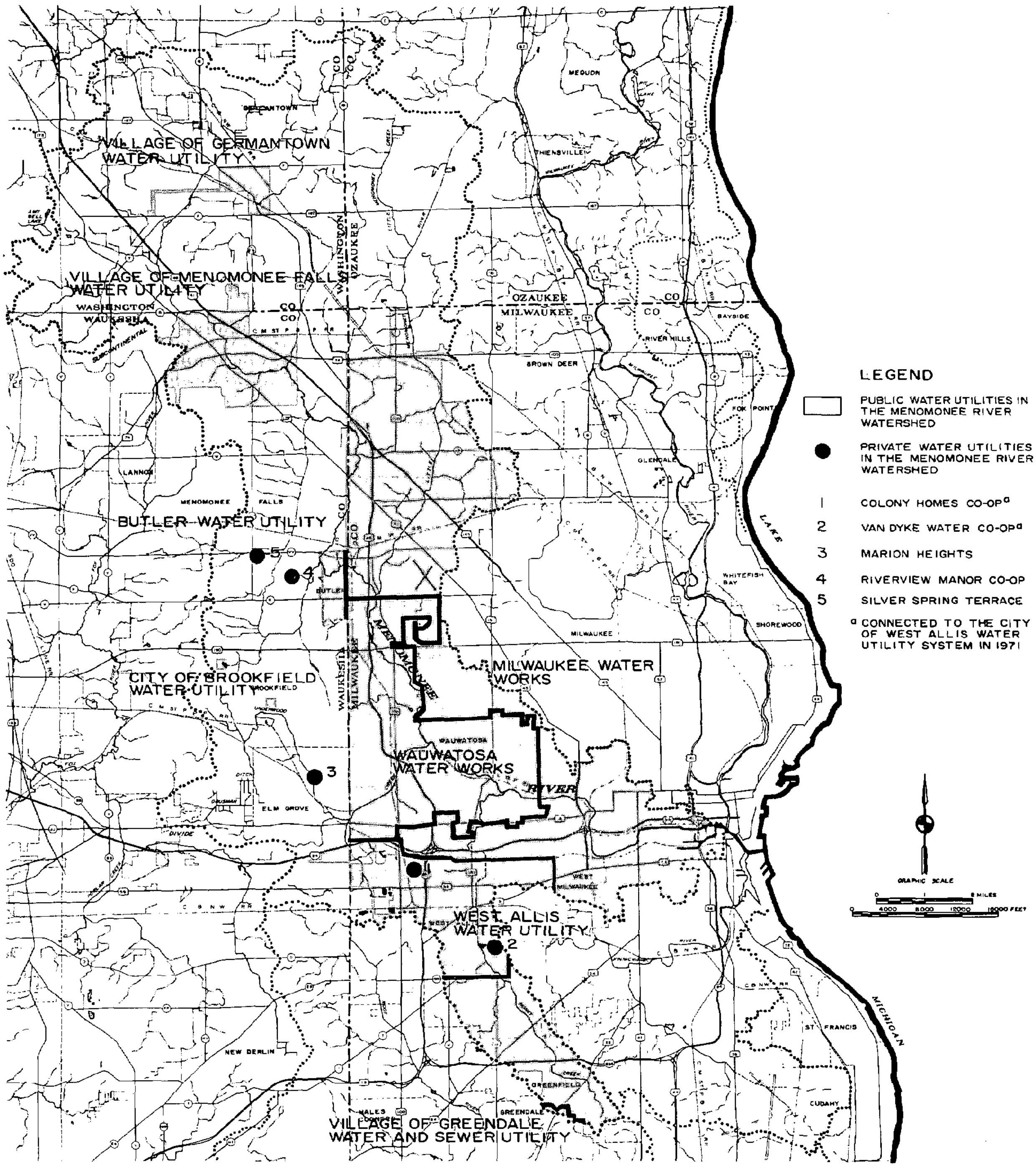


In 1970, about 84 percent of the urban development and about 89 percent of the population of the watershed were served by public sanitary sewerage facilities. Most of the population not served with public sanitary sewers is located in portions of the City of Brookfield and the Village of Menomonee Falls. Almost all of the proposed sanitary sewer service within the watershed is in the planned service area of a single agency: the Metropolitan Sewerage District of the County of Milwaukee.

Source: SEWRPC.

Map 13

PUBLIC WATER SUPPLY SERVICE AREAS IN THE MENOMONEE RIVER WATERSHED: 1970

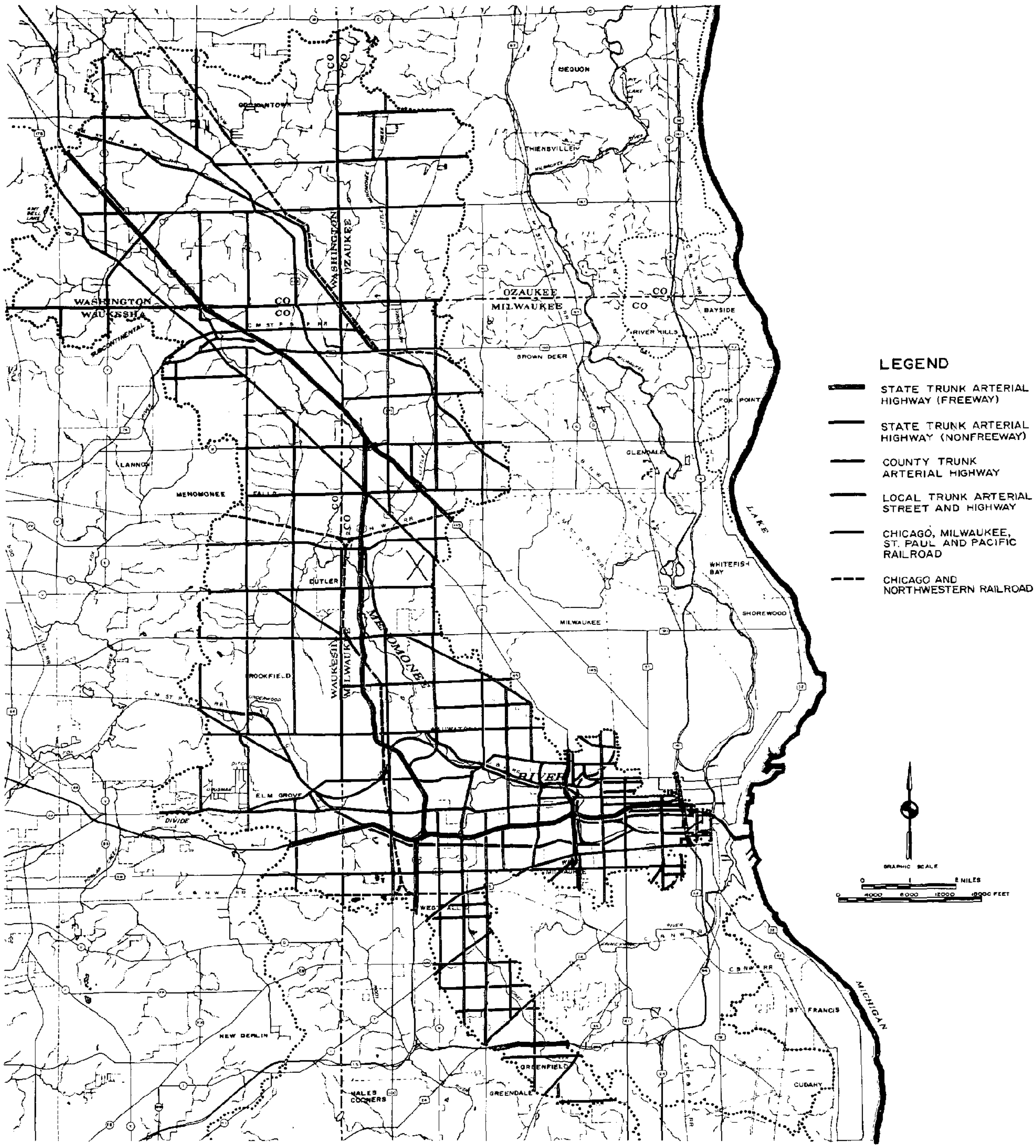


About 77 percent of the present (1970) urban development and about 85 percent of the present population within the watershed are served by public water supply facilities. Lake Michigan water is the major source of municipal water supply within the watershed, currently serving about 68 percent of the present urban development and about 80 percent of the total watershed population.

Source: SEWRPC.

Map 14

ARTERIAL STREET AND HIGHWAY AND TRUNK LINE RAILROAD FACILITIES IN THE MENOMONEE RIVER WATERSHED: 1972



The Menomonee River watershed is served by a well-developed surface transportation system, with a particularly good network of all-weather streets and highways. Passenger transportation is primarily by highway, with goods movement by both rail and highway. The freeway system permits rapid movement by automobile between the lower industrial-commercial-business centers of the watershed and the undeveloped headwater portions of the basin, thereby contributing to the strong urbanization pressures being exerted on those remaining rural headwater areas.

Source: SEWRPC.

River watershed study analyses because it is the considered opinion of the Commission that the estuary and Lake Michigan shoreline areas should be studied after, and separately from, the three tributary watersheds.

DESCRIPTION OF THE WATERSHED: NATURAL RESOURCE BASE

The natural resource base is a primary determinant of the development potential of a watershed and of its ability to provide a pleasant and habitable environment for all forms of life. The principal elements of the natural resource base are climate, physiography, geology, mineral resources, soils, vegetation, water resources, and fish and wildlife resources. Without a proper understanding and recognition of elements comprising the natural resource base and of their interrelationships, human use and alteration of the natural environment proceeds at the risk of excessive costs in terms of both monetary expenditures and destruction of nonrenewable or slowly renewable resources. In this age of high resource demand, urban expansion, and rapidly changing technology, it is especially important that the natural resource base be a primary consideration in any areawide planning effort, since these aspects of contemporary civilization make the underlying and sustaining resource base highly vulnerable to misuse and destruction.

This portion of this chapter identifies and describes the significant elements of the natural resource base of the watershed; indicates and quantifies the spatial distribution and extent of those resources; characterizes, where possible, the quality of each component element of the natural resource base; and seeks to identify those elements and characteristics of the natural resource base which must be considered in the watershed planning process. While all the aforementioned components of the natural resource base are described in this chapter in order to provide an overview of the watershed natural resource base, many are discussed in considerably more detail, as needed, in later chapters. For example, this chapter includes an overview of the surface water resources of the watershed, while the findings of a detailed inventory of surface water quality are presented in Chapter VII.

Climate[2]

General Climatic Conditions: The mid-continental location of the Southeastern Wisconsin Region, far removed from the moderating effect of the oceans, gives the Region and the watershed a typical continental type climate characterized primarily by a continuous progression of markedly different seasons and a large range in annual temperature. Low temperatures during winter are intensified by prevailing frigid northwesterly winds, while summer high temperatures are reinforced by the warm southwesterly winds common during that season.

The Region and the watershed are positioned astride cyclonic storm tracks along which low pressure centers move from the west and southwest. The Region and the watershed also lie in the path of high pressure centers moving in a generally southeasterly direction. This location at the confluence of major migratory air masses results in the watershed as a whole being influenced by a continuously changing pattern of different air masses, and results in frequent weather changes being superimposed on the aforementioned large annual range in weather characteristics, particularly in winter and spring when distinct weather changes normally occur every three or five days. These temporal weather changes consist of marked variations in temperatures, type and amount of precipitation, relative humidity, wind speed and direction, and cloud cover.

In addition to these distinct temporal variations in weather, the watershed—in spite of its relatively small size—exhibits spatial variations in weather due primarily to its proximity to Lake Michigan, particularly during the spring, summer, and fall seasons when the temperature differential between the lake water and the land air masses tends to be the greatest. During these periods, the presence of the lake tends to moderate the climate of the eastern border of the seven-county Southeastern Wisconsin Planning Region in general, and of the Menomonee River watershed in particular. It is common, for example, for midday summer temperatures in shoreline areas to abruptly drop to a temperature level 10°F lower than inland areas because of cooling lake breezes generated by air rising from the warmer land surfaces. This Lake Michigan temperature influence is, however, generally limited to that portion of the watershed lying within a few miles of the shoreline.

Temperature: Watershed temperatures, which exhibit a large annual range, are relevant to the watershed planning and subsequent plan implementation processes. Seasonal temperatures determine the kinds and intensities of the recreational uses to which surface waters may be put, and consequently, the periods over which the highest levels of water quality should be maintained. More importantly, aerobic and anaerobic biochemical processes fundamental to the operation of wastewater treatment plants, which units are normally exposed to the atmosphere, as well as similar processes occurring naturally in surface waters, are temperature dependent, since reaction rates approximately double with each 20°F rise in temperature within the temperature range normally encountered in nature. An ample supply of oxygen is critical to aerobic sewage treatment processes as well as aerobic natural self-purification processes. The supply of oxygen available for such processes is a function of oxygen solubility in water, or the maximum concentration of oxygen that can be retained in solution, which is highly dependent on temperature. For example, a stream at or near freezing temperatures can hold about

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[2] *Unless otherwise indicated, climatic and weather descriptions and data presented herein are based on information extracted from various periodic publications of the National Weather Service, U. S. Department of Commerce, formerly known as the Weather Bureau, U. S. Department of Commerce.*

15 mg/l of dissolved oxygen, but the surface waters of that same stream on a hot 80°F day will have the dissolved oxygen solubility reduced by almost one-half. The summer period is, therefore, critical and limiting in both natural and artificially induced aerobic processes, since oxygen demands are at their annual maximum due to accelerated reaction rates, while the oxygen supply is at its annual minimum because of solubility limitations associated with those high temperatures.

Data for nine selected air temperature observation stations in or near the Menomonee River watershed are presented in Table 9, with the locations of the stations being shown on Map 28. Three of the stations—Germantown, Mount Mary College, and West Allis—are located along a generally north-south line traversing the length of the watershed. Of the remaining six stations, Port Washington, Milwaukee North, and the Milwaukee National Weather Service office are located outside of the watershed along the Lake Michigan shoreline, while West Bend, Hartford, and Waukesha are at inland locations outside of the watershed. Monthly temperature data for the three in-watershed stations are presented graphically in Figure 10. Air temperature and precipitation data used to develop the tables and figures presented in this and the subsequent section of this chapter are for various periods of record ranging from nine years to 50 years. Coincident periods of record were not used because of the widely varying periods of record available—some of which are very short—and because of the absence of readily available data summaries. Although noncoincident periods of record were used, the monthly and annual summary data presented in this chapter are judged to be sufficiently accurate to portray the spatial and temporal variations in watershed temperature and precipitation characteristics. These data indicate the temporal variations, and in some instances the spatial variations, in temperature and the temperature ranges which may be expected to occur within or near the watershed. The temperature data also illustrate how watershed air temperatures lag approximately one month behind summer and winter solstices during the annual cycle, with the result that July is the warmest month in the watershed and January the coldest.

Summer air temperatures throughout the watershed, as reflected by monthly means at the three in-watershed stations for July and August, are in the 69.1°F to 73.3°F range. Average daily maximum temperatures within the watershed for these two summer months are in the 80.4°F to 83.4°F range, whereas average daily minimum temperatures vary from 55.5°F to 62.4°F. With respect to minimum daily temperatures, the meteorological station network is not sufficient to reflect all the effects of topography. During nighttime hours, cold air, because of its greater density, flows into low-lying areas. Because of this phenomenon, the average daily minimum temperatures in these topographically low areas, particularly during the summer months, will be less than those recorded by the meteorological stations.

Winter temperatures for the watershed as measured by monthly means for January and February are in the range of 19.1°F to 24.7°F. Average daily maximum temperatures within the watershed for these two winter months vary from 26.1°F to 31.6°F, whereas average daily minimum temperatures are in the 8.3°F to 15.2°F range.

A comparison of watershed temperature data to that for inland stations located outside of the watershed and stations located outside of the watershed near the Lake Michigan shoreline indicate that most of the watershed has inland temperature characteristics as opposed to lakeshore temperature characteristics. For example, as shown in Table 9, lakeshore stations exhibit summer average daily maximum temperatures that are about 2°F to 3°F lower—because of the cooling effect of Lake Michigan—than those occurring within most of the Menomonee River watershed and at other inland locations.

Air temperature data for the three watershed stations—Germantown, Mount Mary College, and West Allis—as presented in Figure 10 and Table 9 strongly suggest the existence of an "urban heat inland effect."[3,4] Large urban complexes have been observed to exhibit higher air temperatures than surrounding rural areas. This temperature differential is greatest during the evening hours of clear days and is partly attributable to the numerous heat sources within an urban environment. Another factor is the more gradual loss of this heat to the atmosphere because of the dense pattern of the urban structures emitting the heat radiating towards each other rather than into the open atmosphere as in rural areas, and because of the presence of atmospheric contaminants which form a barrier to nighttime radiation from the earth back to the atmosphere.

For all months of the year, average daily minimum temperatures for the West Allis station, which is located in a highly urbanized area, are 2.5 to 5.5°F higher than average daily minimum temperatures at Germantown, which is located in a rural area. Average daily minimum temperatures recorded at the Mount Mary College observation station, which is located within an urban area containing considerable open space, lie between those observed at West Allis and Germantown. Although Germantown temperatures would be expected to be slightly lower than West Allis temperatures because of the latitudinal effect—the Germantown station is located about 15 miles north of the West Allis station—the temperature differential is most pronounced for average minimum daily temperatures, and is too large to be entirely attributable to differences in latitude or topography.

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[3] *K. E. F. Watt, Principles of Environmental Science, Chapter 14, "Urban, Regional and National Planning in Light of Ecological Principles," McGraw-Hill, New York, 1973.*

[4] *W. P. Lowry, Weather and Life: An Introduction to Biometeorology, Chapter 15, "The Climate of the City," Academic Press, New York, 1969.*

Table 9

AIR TEMPERATURE CHARACTERISTICS AT SELECTED LOCATIONS IN AND NEAR THE MENOMONEE RIVER WATERSHED

Month	Observation Station								
	Inland Location Within the Watershed								
	Germantown			Mount Mary College			West Allis		
	Average Daily Maximum[a] (1961-1970)	Average Daily Minimum[a] (1961-1970)	Mean[b] (1945-1970)	Average Daily Maximum[a] (1961-1970)	Average Daily Minimum[a] (1961-1970)	Mean[b] (1946-1970)	Average Daily Maximum[a] (1961-1970)	Average Daily Minimum[a] (1961-1970)	Mean[b] (1951-1970)
January	26.1	8.3	19.1	26.9	10.9	20.3	26.8	10.9	20.4
February	31.2	12.4	22.6	31.6	14.7	23.7	31.5	15.2	24.7
March	41.8	23.4	32.2	42.4	25.4	32.3	42.0	26.3	33.7
April	55.8	33.8	45.5	56.7	36.2	46.4	55.2	37.1	47.0
May	68.1	42.9	55.3	69.3	46.1	56.8	67.9	46.7	57.4
June	78.2	52.5	65.3	79.0	55.9	66.7	78.6	56.6	68.2
July	82.2	57.3	70.0	83.4	61.1	71.7	83.1	62.4	73.3
August	80.4	55.5	69.1	81.7	59.6	70.8	80.8	61.2	72.0
September	72.3	49.0	61.3	73.4	52.6	62.7	72.5	54.1	63.6
October	61.9	40.2	51.6	62.4	43.2	52.5	62.3	44.1	53.0
November	46.1	28.5	36.8	46.9	31.0	37.7	45.8	31.5	38.0
December	31.8	14.6	24.0	32.6	17.5	25.6	32.4	17.9	26.2
Year	56.3	34.9	46.1	57.2	37.9	47.3	56.6	38.7	48.1

Month	Observation Station								
	Inland Location Outside the Watershed								
	West Bend			Hartford			Waukesha		
	Average Daily Maximum[a] (1961-1970)	Average Daily Minimum[a] (1961-1970)	Mean[b] (1930-1970)	Average Daily Maximum[a] (1961-1970)	Average Daily Minimum[a] (1961-1970)	Mean[b] (1954-1970)	Average Daily Maximum[a] (1961-1970)	Average Daily Minimum[a] (1961-1970)	Mean[b] (1930-1970)
January	24.6	8.6	19.4	24.9	7.8	17.2	25.7	10.1	20.0
February	29.6	12.2	22.0	30.7	11.7	21.6	30.7	13.9	22.9
March	40.3	23.5	31.6	42.0	23.1	31.3	41.2	24.7	32.1
April	54.4	34.5	44.8	57.0	34.8	46.8	55.8	36.2	45.6
May	66.9	43.9	56.2	69.7	45.2	57.4	68.0	46.3	56.6
June	76.8	53.8	66.2	79.1	54.5	66.8	78.2	55.9	66.9
July	81.0	58.8	71.3	83.5	58.9	71.3	81.9	61.0	71.9
August	79.6	57.9	69.8	81.9	56.3	70.0	80.3	59.0	70.5
September	71.6	51.0	61.8	73.1	49.8	61.9	72.0	51.9	62.3
October	60.9	41.9	51.1	62.5	40.9	51.6	61.6	42.3	51.4
November	45.2	29.4	36.3	45.7	29.3	36.3	45.8	30.5	36.9
December	30.6	15.5	24.0	30.6	14.5	23.3	31.3	16.7	24.6
Year	55.1	35.9	46.2	56.7	35.6	46.3	56.0	37.4	46.8

In summary, then, the air temperature data strongly suggest the existence of an urban heat island effect at several locations in the Menomonee River watershed. One consequence of this effect is an increase in precipitation and cloudiness that is convectively produced as a result of air rising from the warmer urban areas. Such effects are probably present in the urban portions of the Menomonee River watershed, and are reflected in the hydrologic analysis in that the precipitation data used in that analysis is for both rural and urban stations in and near the watershed.

The growing season, which is defined as the number of days between the last 32°F freeze in spring and the first in the fall, averages about 150 days for the rural headwater areas of the watershed. The last 32°F frost in the spring normally occurs during the first half of May for those headwater areas, whereas the first freeze in the fall usually occurs during the first half of October.

Extreme high and low temperatures for the watershed, based on 30 years or more of historic records at observation stations distributed throughout the Region, indicate that extreme high temperatures within or near the watershed have ranged from 104°F in the extreme eastern portion of the watershed to about 108°F in its western extremities. Extreme low temperatures have ranged from about -20°F in the easternmost portion of the watershed to about -30°F in the remainder of the watershed.

Precipitation: Precipitation within the watershed takes the form of rain, sleet, hail, and snow, and ranges from gentle showers of trace quantities to destructive thunderstorms, as well as major rainfall-snowmelt events causing property and crop damage, inundation of poorly drained areas, and stream flooding. Existing sewerage system problems such as overflows from combined sewers in certain urban areas are the direct result of even small precipitation events. Rainfall events may also cause sepa-

Table 9 (continued)

Month	Observation Station									Watershed Summary		
	Lakeshore Location Outside the Watershed											
	Port Washington			Milwaukee (North Side)			Milwaukee-National Weather Service					
	Average Daily Maximum[a] (1961-1970)	Average Daily Minimum[a] (1961-1970)	Mean[b] (1960-1970)	Average Daily Maximum[a] (1961-1970)	Average Daily Minimum[a] (1961-1970)	Mean[b] (1951-1970)	Average Daily Maximum[a] (1962-1970)	Average Daily Minimum[a] (1962-1970)	Mean[b] (1921-1970)	Average Daily Maximum[c]	Average Daily Minimum[c]	Mean[d]
January . . .	26.1	10.1	18.8	28.3	12.2	21.0	25.2	10.5	21.0	26.1	9.9	19.7
February . .	30.5	14.0	22.4	33.2	16.5	25.3	29.3	13.7	24.0	30.9	13.8	23.2
March . . .	39.1	24.2	30.9	42.6	23.8	33.0	40.1	24.6	32.7	41.3	24.3	32.2
April	50.5	34.3	42.6	55.4	36.3	46.4	54.2	35.5	44.6	55.0	35.4	45.5
May	60.8	42.9	51.7	68.1	45.7	56.6	65.3	44.5	54.5	67.1	44.9	55.8
June	71.8	52.1	61.5	77.8	55.2	66.4	75.2	54.3	65.0	77.2	54.5	65.9
July	76.7	59.2	68.9	81.9	61.1	71.5	79.6	60.7	71.0	81.5	60.1	71.2
August . . .	76.7	58.3	67.6	80.3	60.7	71.0	78.1	59.0	69.8	80.0	58.6	70.1
September . .	69.1	51.7	60.7	73.2	53.6	63.3	70.2	51.9	62.3	71.9	51.7	62.2
October . . .	59.3	41.8	50.6	63.1	43.9	52.7	60.6	42.0	51.4	61.6	42.3	51.8
November . .	45.3	30.4	39.0	47.5	32.1	38.6	45.5	30.4	37.3	46.0	30.3	37.4
December . .	32.1	17.0	24.3	33.3	19.2	26.6	31.4	17.3	25.6	31.8	16.7	24.9
Year	53.2	36.3	44.9	57.1	38.4	47.7	54.6	37.0	46.6	55.9	36.9	46.7

[a] *The monthly average daily maximum temperature and the monthly average daily minimum temperature are obtained by using daily measurements to compile an average for each month in the indicated period of record; the results are then averaged for all months in the period of record.*

[b] *The monthly mean temperature is the mean of the average daily maximum temperature and the average daily minimum temperature for each month for the indicated period of record.*

[c] *The monthly average daily maximum and minimum temperatures for the Region as a whole were computed as averages of the corresponding values for the nine observation stations.*

[d] *The monthly mean for the Region as a whole is the average of the monthly means for the nine observation stations.*

Source: National Weather Service and SEWRPC.

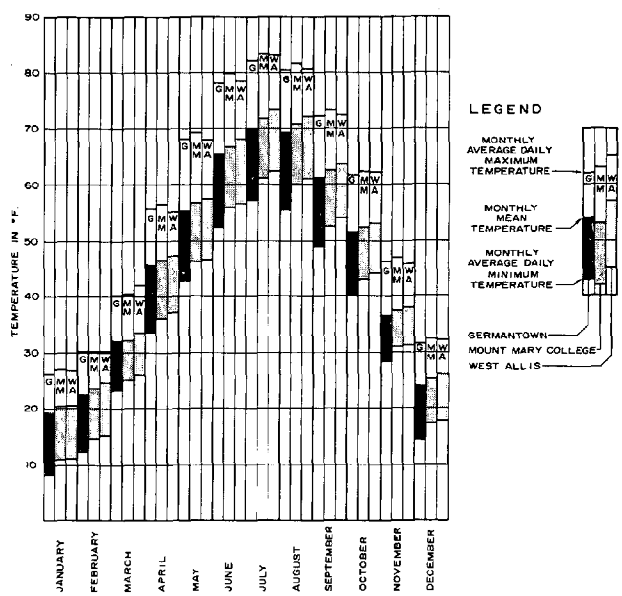
rate sanitary sewerage systems to surcharge and overflow to surface watercourses, and may require sewage treatment plants to bypass large volumes of partially treated or untreated sewage in excess of the hydraulic capacity of the plants. Such surcharging of separate sanitary sewerage systems is caused by the entry of excessive quantities of rain, snowmelt, and groundwater into the sanitary sewers via manholes, building sewers, building downspouts, and foundation drain connections, and by infiltration through faulty sewer pipe joints, manhole structures, and cracked pipes.

Total precipitation as well as snowfall data for nine observation stations in or near the Menomonee River watershed are presented in Table 10, and the location of each is shown on Map 28. Monthly total precipitation and snowfall observations for the three in-watershed stations are presented graphically in Figure 11. The data illustrate the temporal variations in the type and amount of precipitation that normally occurs within or near the watershed.

The average annual total precipitation in the watershed and immediate surroundings, based on a numerical average of data for the nine representative stations, is 29.4 inches, expressed as water equivalent, while the average annual snow and sleet measured as snow and sleet is 40.3 inches. The average annual total precipitation for the watershed itself as determined by the Thiessen Polygon Network method is 29.1 inches, while the average annual accumulation of snow and sleet is 42.0 inches.

Figure 10

AIR TEMPERATURE CHARACTERISTICS AT SELECTED LOCATIONS IN THE MENOMONEE RIVER WATERSHED



Source: National Weather Service, and SEWRPC.

Table 10

PRECIPITATION CHARACTERISTICS AT SELECTED LOCATIONS IN AND NEAR THE MENOMONEE RIVER WATERSHED

	Observation Station					
	Inland Location Within the Watershed					
	Germantown		Mount Mary College		West Allis	
Month	Average Total Precipitation (1945-1970)	Average Snow and Sleet (1961-1970)	Average Total Precipitation (1946-1970)	Average Snow and Sleet (1961-1970)	Average Total Precipitation (1951-1970)	Average Snow and Sleet (1961-1970)
January	1.13	9.9	1.50	10.4	1.39	10.0
February	0.82	7.3	1.11	10.1	1.02	7.0
March	1.74	12.1	2.16	8.7	1.97	7.5
April	2.72	1.3	3.10	1.7	3.04	1.1
May	2.89	0.1	2.96	Trace	2.78	Trace
June	3.53	0.0	3.58	0.0	3.81	0.0
July	3.37	0.0	3.94	0.0	3.61	0.0
August	3.03	0.0	2.91	0.0	3.01	0.0
September	3.19	Trace	2.84	Trace	3.03	0.0
October	2.10	0.2	2.27	Trace	2.46	Trace
November.	1.99	1.0	2.01	0.8	2.21	0.4
December	1.33	12.4	1.72	10.3	1.59	8.4
Year	27.84	44.3	30.10	42.0	29.92	34.4

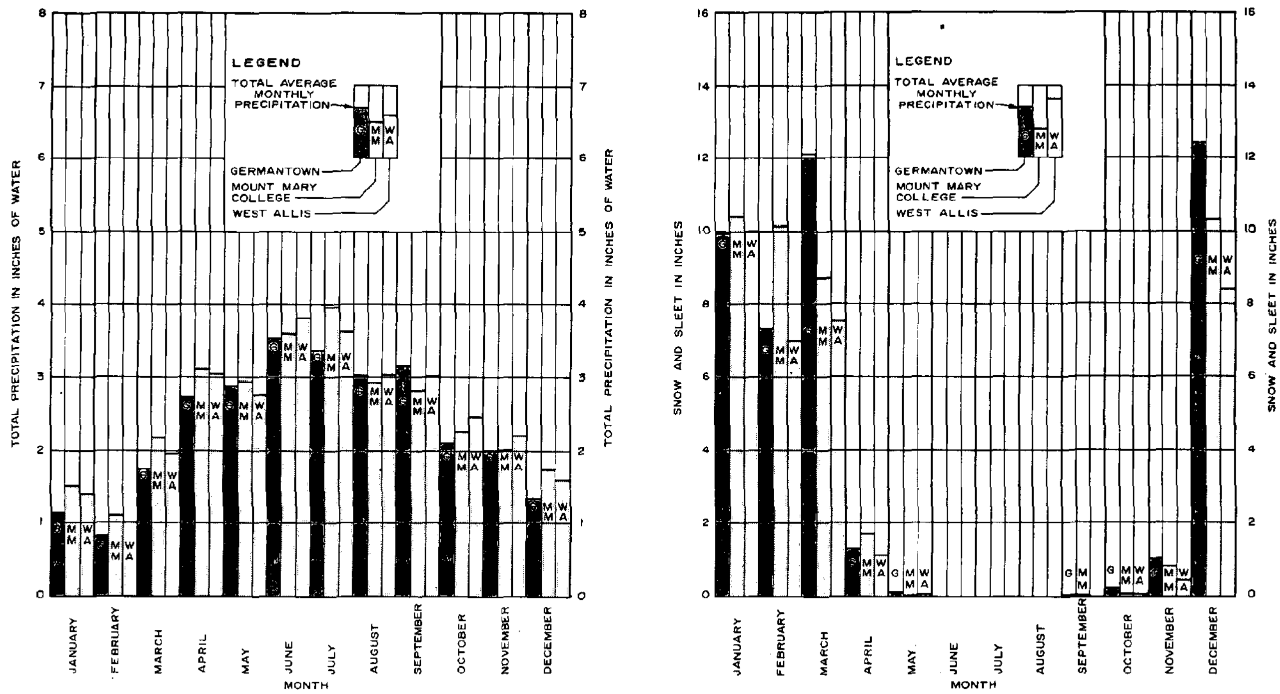
	Observation Station					
	Inland Location Outside the Watershed					
	West Bend		Hartford		Waukesha	
Month	Average Total Precipitation (1930-1970)	Average Snow and Sleet (1961-1970)	Average Total Precipitation (1954-1970)	Average Snow and Sleet (1961-1970)	Average Total Precipitation (1930-1970)	Average Snow and Sleet (1961-1970)
January	1.55	12.4	1.06	8.8	1.63	9.9
February	1.18	4.8	0.87	5.3	1.14	6.8
March	1.92	11.3	1.79	8.8	2.10	9.1
April	2.57	1.3	2.83	1.2	2.67	0.9
May	2.98	Trace	3.23	Trace	3.39	Trace
June	3.82	0.0	3.96	0.0	3.56	0.0
July	3.49	0.0	3.79	0.0	3.28	0.0
August	2.86	0.0	2.75	0.0	3.11	0.0
September	3.59	Trace	4.02	0.0	3.05	Trace
October	2.28	0.2	2.68	0.1	2.17	0.1
November	2.07	1.5	1.88	0.9	2.20	1.2
December	1.43	12.4	1.46	8.6	1.55	10.1
Year	29.74	43.9	30.32	33.7	29.85	38.1

	Observation Station						Watershed Summary			
	Lakeshore Locations Outside the Watershed									
	Port Washington		Milwaukee (North Side)		Milwaukee-National Weather Service				Average Based on the Thiessen Polygon Method	
Month	Average Total Precipitation (1941-1970)	Average Snow and Sleet (1961-1970)	Average Total Precipitation (1951-1970)	Average Snow and Sleet (1961-1970)	Average Total Precipitation (1921-1970)	Average Snow and Sleet (1961-1970)	Average Total Precipitation	Average Snow and Sleet	Total Precipitation	Snow and Sleet
January . . .	1.40	12.8	1.53	12.7	1.57	12.1	1.42	11.0	1.32	10.2
February . .	1.03	8.7	1.11	8.5	1.25	8.8	1.06	7.5	0.97	8.3
March . . .	1.90	9.3	2.04	10.0	2.20	10.8	1.98	9.7	1.94	10.0
April	2.82	1.1	3.03	1.4	2.65	2.2	2.83	1.4	2.92	1.8
May	2.97	Trace	2.98	Trace	2.87	Trace	3.02	Trace	2.90	Trace
June	3.19	0.0	3.78	0.0	3.38	0.0	3.62	0.0	3.60	0.0
July	3.22	0.0	3.79	0.0	2.94	0.0	3.49	0.0	3.61	0.0
August . . .	2.71	0.0	2.87	0.0	2.75	0.0	2.89	0.0	2.98	0.0
September . .	3.33	Trace	3.04	Trace	3.11	0.0	3.25	Trace	3.04	Trace
October . . .	2.08	0.2	2.42	0.1	2.10	0.1	2.28	0.1	2.23	0.1
November . .	2.05	0.6	1.96	0.4	2.06	0.7	2.05	0.8	2.04	0.8
December . .	1.56	8.9	1.62	6.6	1.58	10.7	1.54	9.8	1.52	10.8
Year	28.26	41.6	30.17	39.7	28.46	45.4	29.43	40.3	29.07	42.0

Source: National Weather Service and SEWRPC.

Figure 11

PRECIPITATION CHARACTERISTICS AT SELECTED LOCATIONS IN THE MENOMONEE RIVER WATERSHED



Source: National Weather Service, and SEWRPC.

Average total monthly precipitation for the watershed, based on the Thiessen Polygon Network method, ranges from 0.97 inch in February to 3.61 inches in July. The principal snowfall months are December, January, February, and March, when average monthly snowfalls are 10.8, 10.2, 8.3, and 10.0 inches, respectively, and during which time 94 percent of the average annual snowfall may be expected to occur. Snowfall is the predominant form of precipitation during these months, totaling approximately 70 percent of the total precipitation expressed as water equivalent. Approximately 19 inches, or two-thirds of the average annual precipitation, normally occurs during the late April through mid-October growing season, primarily as rainfall. Assuming that 10 inches of measured snowfall is equivalent to one inch of water, the average annual snowfall of 42 inches is equivalent to 4.2 inches of water, and therefore only 15 percent of the average annual total precipitation occurs as snowfall. It is of interest to note that approximately one-fourth of the 29-inch average annual precipitation leaves the watershed as streamflow; the remaining three-fourths being lost from the watershed primarily as evapotranspiration.

Extreme precipitation event data through 1970 for three stations—West Bend, Waukesha, and the Milwaukee National Weather Service Office—located near the Menomonee River watershed and having relatively long periods of record, are presented in Table 11. Inasmuch as these long-term records are for stations located near to, and around the periphery of, the Menomonee River watershed, they are representative of the extreme precipitation events that have occurred within the watershed.

Based on the tabulated data, annual precipitation within the watershed and the immediate surroundings has varied from a low of approximately 17 inches, or about 58 percent of the area average, to a high of approximately 50 inches, or about 68 percent above the average. Annual seasonal snowfall has varied from a low of approximately five inches, or about 12 percent of the area average, to a high of approximately 109 inches, or about 170 percent above the average.

The maximum monthly precipitation at the four representative stations is 13.17 inches, recorded at West Bend in August of 1924, and the maximum monthly snowfall is 56 inches measured at Waukesha in January 1918. The maximum 24-hour rainfall is 7.58 inches as recorded on August 4, 1924 at West Bend, while the maximum 24-hour snowfall is 30 inches measured at Racine on February 19 and 20, 1898.

Snow Cover: The likelihood of snow cover and the depth of snow on the ground are important precipitation related factors that influence the planning, design, construction, and maintenance of public utilities. Snow

Table 11

EXTREME PRECIPITATION EVENTS FOR LONG-TERM STATIONS NEAR THE MENOMONEE RIVER WATERSHED

Observation Station[a]		Period of Precipitation Records Except Where Indicated Otherwise	Total Precipitation (Water Equivalent)											
			Maximum Annual		Minimum Annual		Maximum Monthly			Maximum Daily			
Name	County		Amount	Year	Amount	Year	Amount	Month	Year	Amount	Day	Month	Year
Milwaukee	Milwaukee	1870-1970	50.36[b]	1876	18.69[b]	1901	10.03	June	1917	5.76[c]	22-23	June	1917
Racine	Racine	1895-1970	48.33	1954	17.75	1910	10.98	May	1933	4.00	11	September	1933
Waukesha	Waukesha	1892-1970	43.57	1938	17.30	1901	11.41	July	1952	5.09	18	July	1952
West Bend	Washington	1922-1970	40.52	1938	19.72	1901	13.17[g]	August	1924	7.58[g]	4	August	1924

Observation Station[a]		Snowfall										
		Maximum Annual		Minimum Annual		Maximum Monthly			Maximum Daily			
Name	County	Amount	Year	Amount	Year	Amount	Month	Year	Amount	Day	Month	Year
Milwaukee	Milwaukee	109.0[d]	1885-1886	11.0[d]	1884-1885	52.6	January	1918	20.3[e]	4-5	February	1924
Racine	Racine	85.0	1897-1898	5.0[f]	1901-1902	38.0	February	1898	30.0[e]	19-20	February	1898
Waukesha	Waukesha	83.0[f]	1917-1918	9.1	1967-1968	56.0	January	1918	20.0[e]	5-6	January	1918
West Bend	Washington	86.5	1935-1936	19.6	1967-1968	38.0	January	1943	21.0	10-11	December	1970

[a] *An observation station was included if a minimum of 30 years of record was available.*

[b] *Based on the period 1841-1970.*

[c] *Maximum precipitation for a 24-hour period.*

[d] *Maximum and minimum snowfalls for a winter season.*

[e] *Maximum snowfall for a 24-hour period.*

[f] *Estimated from incomplete records.*

[g] *Based on the period 1895-1959 as reported in "A Survey Report for Flood Control on the Milwaukee River and Tributaries," U. S. Army Engineer District, Chicago, Corps of Engineers, November 1964.*

Source: *Wisconsin Statistical Reporting Service, National Weather Service, U. S. Army Corps of Engineers, and SEWRPC.*

cover, particularly early in the winter season, significantly influences the depth and duration of frozen ground, which in turn affects engineered works involving extensive excavation and underground construction. Accumulated snow depth at a particular time and place is primarily dependent on antecedent snowfall, rainfall, and temperature characteristics, and the amount of solar radiation. Rainfall is relatively unimportant as a melting agent, but can, because of compaction effects, significantly affect the depth of snow cover on the ground.

Snow depth as measured at Milwaukee for the 70-year period from 1900 through 1969 and published in "Snow and Frost in Wisconsin," a 1970 Wisconsin Statistical Reporting Service report, is summarized and presented in Table 12. It should be emphasized that the tabulated data pertain to snow depth on the ground as measured at the place and time of observation, and are not a direct measure of average snowfall. Recognizing that snowfall and temperatures, and therefore snow accumulation on the ground, vary spatially within the watershed, the Milwaukee area data presented in Table 12 should be considered only as an approximation of conditions throughout the watershed. As indicated by the data, snow cover is most likely during the months of December, January, and February, during which at least a 0.40 probability exists of having one inch or more of snow cover at Milwaukee. Furthermore, during January and the first half of February, at least a 0.25 probability exists of having five or more inches of snow on the ground. During March, the month in which severe spring snowmelt-rainfall flood events are most likely to occur, at least a 0.30 probability exists of having one inch or more of snow on the ground during the first half of the month, while the probability of having that much snow cover diminishes to 0.07 by the end of the month.

Table 12

SNOW COVER PROBABILITIES AT MILWAUKEE BASED ON DATA FOR THE PERIOD 1900-1970

Date		Snow Cover[a]									
		1.0 Inch or More		5.0 Inches or More		10.0 Inches or More		15.0 Inches or More		Average (Inches)	
Month	Day	Number of Occurrences[b]	Probability of Occurrence[c]	Number of Occurrences[b]	Probability of Occurrence[c]	Number of Occurrences[b]	Probability of Occurrence[c]	Number of Occurrences[b]	Probability of Occurrence[c]	Per Occurrence[d]	Overall[e]
November	15	5	0.07	0	0.00	0	0.00	0	0.00	1.2	0.09
	30	12	0.17	1	0.01	1	0.01	0	0.00	2.8	0.49
December	15	33	0.47	10	0.14	0	0.00	0	0.00	3.3	1.54
	31	32	0.46	9	0.13	1	0.01	0	0.00	3.6	1.66
January	15	43	0.61	17	0.24	4	0.06	2	0.03	4.9	2.94
	31	48	0.69	22	0.31	9	0.13	4	0.06	6.2	4.26
February	15	44	0.63	23	0.33	7	0.10	3	0.04	6.0	3.69
	28	27	0.39	8	0.11	3	0.04	1	0.01	4.5	1.69
March	15	23	0.33	6	0.09	4	0.06	0	0.00	3.9	1.21
	31	5	0.07	1	0.01	1	0.01	0	0.00	3.4	0.24

[a] *Data pertains to snow depth on the ground as it was measured at the time and place of observation, and is not a direct measure of average snowfall.*

[b] *Number of occurrences is the number of times during the 70 year period of record when measurements revealed that the indicated snow depth was equaled or exceeded on the indicated date.*

[c] *Probability of occurrence for a given snow depth and date is computed by dividing the number of occurrences by 70, and is defined as the probability that the indicated snow cover will be reached or exceeded on the indicated date.*

[d] *Average snow cover per occurrence is defined as the sum of all snow cover measurements in inches for the indicated date divided by the number of occurrences for that date, that is, the number of times in which 1.0 inch or more of snow cover was recorded.*

[e] *Overall average snow cover is defined as the sum of all snow cover measurements in inches for the indicated date divided by 70, that is, the number of observation times.*

Source: Wisconsin Statistical Reporting Service, National Weather Service, and SEWRPC.

The aforementioned table facilitates an estimation of the probability that a given snow cover will exist or be exceeded at any given time, and should, therefore, be useful in planning winter outdoor work and construction activities as well as in estimating runoff for hydrologic purposes. There is, for example, only a 0.07 probability of having one or more inches of snow cover on November 15 of any year, whereas there is a much higher probability, 0.61, of having that much snow cover on January 15.

Frost Depth: Ground frost or frozen ground refers to that condition in which the ground contains variable amounts of water in the form of ice. Frost influences hydrologic processes, particularly the percent of rainfall or snowmelt that will run off the land directly to sewerage systems and to surface watercourses in contrast to that which will enter and be temporarily detained in the soil. Anticipated frost conditions influence the design of engineered works in that structures and facilities are designed so as to either prevent the accumulation of water and, therefore, the formation of damaging frost, as in the case of pavements and retaining walls, or structures and facilities are designed so as to be partially or completely located below the frost susceptible zone in the soil, as in the case of foundations and water mains. For example, in order to avoid or minimize the danger of structural damage, foundation footings must be placed at a sufficient depth in the ground so as to be below that zone in which the soil may be expected to contract, expand, or shift due to frost action. A similar consideration exists in the design and construction of sanitary sewers.

Snow cover is a primary determinant of the depth of frost penetration and of the duration of frozen ground. The thermal conductivity of snow cover is less than one-fifth that of moist soil, so that heat loss from the soil to the cold atmosphere is greatly inhibited by an insulating snow cover. An early, major snowfall that is retained on the ground as a substantial snow cover will inhibit or prevent frost development in unfrozen ground, and may even result in a reduction or elimination of frost in already frozen ground. If an early, significant snow cover is maintained by additional regular snowfall throughout the winter season, frozen ground may not develop at all, or at most, a relatively small frost penetration will occur. Frost depth is also dependent on vegetal cover and soil type. Assuming similar soil types, for example, frost will penetrate more deeply into bare, unprotected soil than into soil covered with an insulating layer of sod.

Frost conditions for the Region are available on a bimonthly basis for the months of November to April as shown in Table 13, and are based upon data for an eight-year period of record, extending from 1961 through 1968 as set forth in the report "Snow and Frost in Wisconsin," published in 1970 by the Wisconsin Statistical Reporting Service. These data are provided for representative locations on a weekly basis by funeral directors and cemetery officials. Since cemetery soils are normally overlain by an insulating layer of turf, the frost depths shown in Table 13 should be considered minimum values. Frost depths in excess of four feet have been observed in southeastern Wisconsin. During the period that frost depth observations have been made in southeastern Wisconsin, one of the deepest regionwide frost penetrations occurred in early March 1963, when 25 to 30 inches of frost occurred throughout the watershed.

The data indicate that frozen ground is likely to exist throughout the watershed for approximately four months each winter season, extending from late November through March, with more than six inches of frost normally occurring during January, February, and the first half of March. Historical data indicate that the most severe frost conditions normally occur in February, when 15 or more inches of frost may be expected.

Evaporation: Evaporation is the natural process whereby water is transformed from the liquid or solid state to the vapor state and returned to the atmosphere. Total evaporation includes evaporation from water and snow surfaces and directly from the soil, and also includes evaporation of precipitation intercepted by vegetation. The magnitude and annual variation in evaporation from water surfaces and the relation of the evaporation to precipitation is important because of the key role of this process in the hydrologic cycle of the Menomonee River watershed.

Limited evaporation data available for the watershed and immediate surroundings indicate an average annual evaporation from a water surface of about 29 inches, with about three-quarters of this, or 23.6 inches, occurring during the six-month May through October period. As indicated earlier in this chapter and summarized in Table 10, the average annual precipitation for the watershed and environs is about 29 inches, that is, equal to the average annual evaporation. During the aforementioned six-month May through October period, watershed precipitation is about 18.4 inches, and therefore evaporation from a water surface may be expected to exceed precipitation by about five inches during this period.

Wind: Prevailing winds in the Region follow a clockwise pattern in terms of the prevailing direction over the seasons of the year, being northwesterly in the late fall and winter, northeasterly in the spring, and southwesterly in the summer and early fall. Wind velocities in the Menomonee River watershed may be expected to be less than five miles per hour about 15 percent of the time, between 5 and 15 miles per hour about 60 percent of the time, and in excess of 15 miles per hour about 25 percent of the time.

Daylight and Sky Cover: The annual variation in the time of sunrise and sunset and the daily hours of sunlight for the watershed are presented in Figure 12. Expected sky cover information, in the form of the expected percent of clear, partly cloudy, and cloudy days each month, is also summarized in Figure 12. These daylight and sky cover data have some value in planning outdoor construction and maintenance work, and are also useful in analyzing and explaining diurnal changes in observed surface water quality. For example, marked changes in measured stream dissolved oxygen levels are normally correlated with the transition from daytime to nighttime conditions, when photosynthetic oxygen production by algae and aquatic plants is replaced by oxygen utilization through respiration by those algae and aquatic plants. As illustrated in Figure 12, the duration of daylight ranges from a minimum of 9.0 hours on about December 22, the winter solstice, to a maximum of 15.4 hours on about June 21, the summer solstice.

Mean monthly sky cover for the sunrise to sunset period varies somewhat during the year. The smallest amount of daytime sky cover may be expected to occur during the four-month July through October period, when the mean monthly sky cover is at or slightly above 0.5. Clouds or other obscuring phenomena are most prevalent during the five months of November through March, when the mean monthly daytime sky cover is about 0.7. The tendency for maximum average sky cover to occur in the

Table 13

AVERAGE FROST DEPTH IN THE MENOMONEE RIVER WATERSHED NOVEMBER TO APRIL

Month and Day	Nominal Frost Depth (Inches)[a]
November 30	1
December 15	3
December 31	3
January 15	9
January 31	12
February 15	15
February 28	15
March 15	12
March 31	6
April 15	1

[a] *Based on 1960-1968 frost depth data for cemeteries as reported by funeral directors and cemetery officials. Since cemeteries have soils that are overlain by an insulating layer of turf, the mapped frost depths should be considered as minimum values.*

Source: Wisconsin Statistical Reporting Service, "Snow and Frost in Wisconsin," June 1970.

winter and minimum average sky cover to occur in the summer is also illustrated by examining the expected relative number of days classified as clear, partly cloudy, and cloudy for months in each of those seasons. During the summer months, as shown in Figure 12, about one-third of the days may be expected to be categorized as clear, one-third as partly cloudy, and one-third as cloudy. Greater sky cover occurs in the winter, however, when over one-half of the days are classified as cloudy, with the remainder being approximately equally divided between partly cloudy and clear.

Physiography

The 137 square mile Menomonee River watershed is a narrow, irregularly shaped drainage basin, with its major axis oriented approximately north and south. Its length—measured between the northernmost and southernmost points in the watershed—is approximately 23 miles, and its maximum width, which occurs in the lower third of the watershed along a line extending from the Milwaukee Harbor directly west to the Menomonee River watershed divide, is 12 miles. The middle portion of the watershed is about five miles wide, while the upper headwater area is approximately nine miles in width.

Topographic and Physiographic Features: Watershed topography or variation in elevation, is shown on Map 15. Watershed physiographic features, or surficial land forms, have been determined largely by the underlying bedrock and the overlying glacial deposits of the watershed. There is evidence of four major stages of glaciation in southeastern Wisconsin. The last and most influential in terms of present physiography and topography was the Wisconsin stage, which is believed to have ended about 11,000 years ago.

The Niagara cuesta on which the watershed lies is a gently eastward sloping bedrock surface. The topography in this section is asymmetrical as shown on Map 15, with the eastern border of the watershed being generally lower—about 150 to 300 feet—in elevation than the western border. Glacial deposits overlying the bedrock formations form the irregular surface topography of the watershed, characterized by rounded hills or groups of hills, ridges, broad undulating plains, and poorly drained wetlands.

Interlobate deposits known as the Kettle Moraine, left between the Green Bay and Lake Michigan lobes, or tongues, of the continental glacier which moved in a generally southerly direction from its point of origin in what is now Canada, lie to the west of the Menomonee River watershed. The northwest portion of the watershed lies closest to the Kettle Moraine, and contains rolling ground moraine similar to, but more subdued than, the kettle and kame topography of the Kettle Moraine. This area of rolling ground moraine gives the watershed its highest elevations and areas of greatest local relief.

Surface elevations within the watershed range from a high of approximately 1,120 feet above sea level in the Town of Richfield (southeast one-quarter of Section 24) in Washington County, to approximately 580 feet above sea level in the Menomonee River industrial valley, a maximum relief of 540 feet. The areas of greatest local relief are located in the northwest portion of the watershed along the north-south boundary between the Town of Richfield and the Village of Germantown.

Most of the watershed is covered by gently sloping ground moraine—heterogeneous material deposited beneath the ice—and moraines consisting of material deposited at the forward margins of the ice sheet, and outwash plains formed by the action of flowing glacial meltwater. Glacial land forms are of economic significance because some are prime sources of sand and gravel needed for highway and other construction purposes. Because of their beauty and desirability for homesites, glacial land forms also serve as effective indicators of those rural areas of the watershed likely to experience concentrated residential development. An example of such an area is the attractive rolling ground moraine area in the northwest portion of the watershed, which provides an excellent view of the Kettle Moraine to the west.

Topography is important to watershed planning since it is one of the important factors determining the hydrologic response of a watershed to rainfall and rainfall-snowmelt events, and since topographic considerations enter into the selection of sites and routes for public utilities and facilities such as sewerage and water supply systems and highways. Some type of large scale mapping is available for about 135 square miles, or about 98 percent, of the total watershed area (see Map 16). Of that total, 56 square miles, representing about 42 percent of the watershed, is covered by large scale topographic mapping prepared using SEWRPC recommended procedures. For the remaining area, other large scale topographic mapping and sanitary and storm sewer maps either with or without street grade elevations are available. The scale, contour interval, date, and source of mapping and other selected information are presented in Table 14. The above mapping, together with 1" = 400' scale aerial photographs available for the entire watershed, were used extensively during the watershed planning process and should be equally valuable during implementation of the Menomonee River watershed plan.

Surface Drainage: As already noted, a major subcontinental divide that separates Mississippi River basin drainage from Great Lakes-St. Lawrence River basin drainage forms much of the western boundary of the Menomonee River watershed. In addition to the physical significance of the subcontinental divide—it establishes the overall easterly direction of Menomonee River watershed surface drainage—the subcontinental divide also carries with it certain legal constraints on the diversion of water across the divide. Also of significance are the water quality requirements imposed on the watershed as a result of its being tributary to Lake Michigan.

The Fox River and Rock River watersheds lie west of the Menomonee River watershed and of the subcontinental divide. On the north and east, the Menomonee River watershed adjoins the large Milwaukee River watershed, while the Kinnickinnic River, Oak Creek, and Root

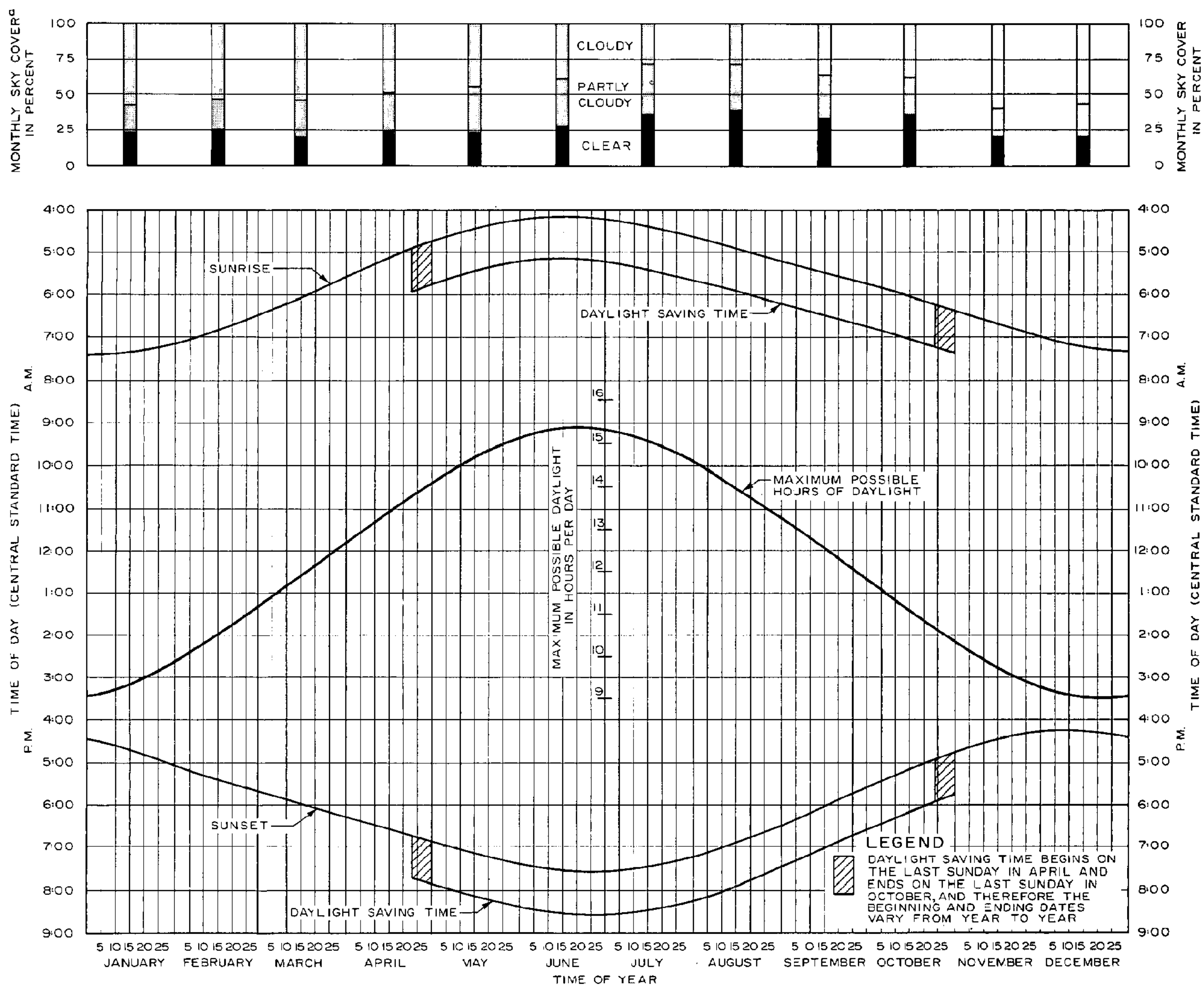
River watersheds lie to the south of the Menomonee River watershed. Comprehensive watershed plans have been completed and adopted by the Commission for three of the six watersheds contiguous to the Menomonee River watershed—the Root River, Fox River, and Milwaukee River watersheds—while in December 1974 the Commission published a prospectus for one of the remaining three contiguous watersheds—the Kinnickinnic River watershed.

Surface drainage within the watershed is very diverse with respect to channel shape and slope, the degree of stream sinuosity, and floodland shape and width. The heterogeneous character of the surface drainage system is partly due to the natural effects of recent glaciation superimposed on the bedrock geology, and partly due to the extensive channel modifications evident in the lower watershed.

The main stem of the Menomonee River begins its 30-mile route to Lake Michigan from its point of origin in a large woodland-wetland area located in Section 12, Town 9 North, Range 20 East, in the extreme northeast corner of the Village of Germantown. From there it flows in a generally southwesterly direction past the original Village of Germantown and then southerly into the

Figure 12

SUNRISE, SUNSET, AND SKY COVER IN THE MENOMONEE RIVER WATERSHED

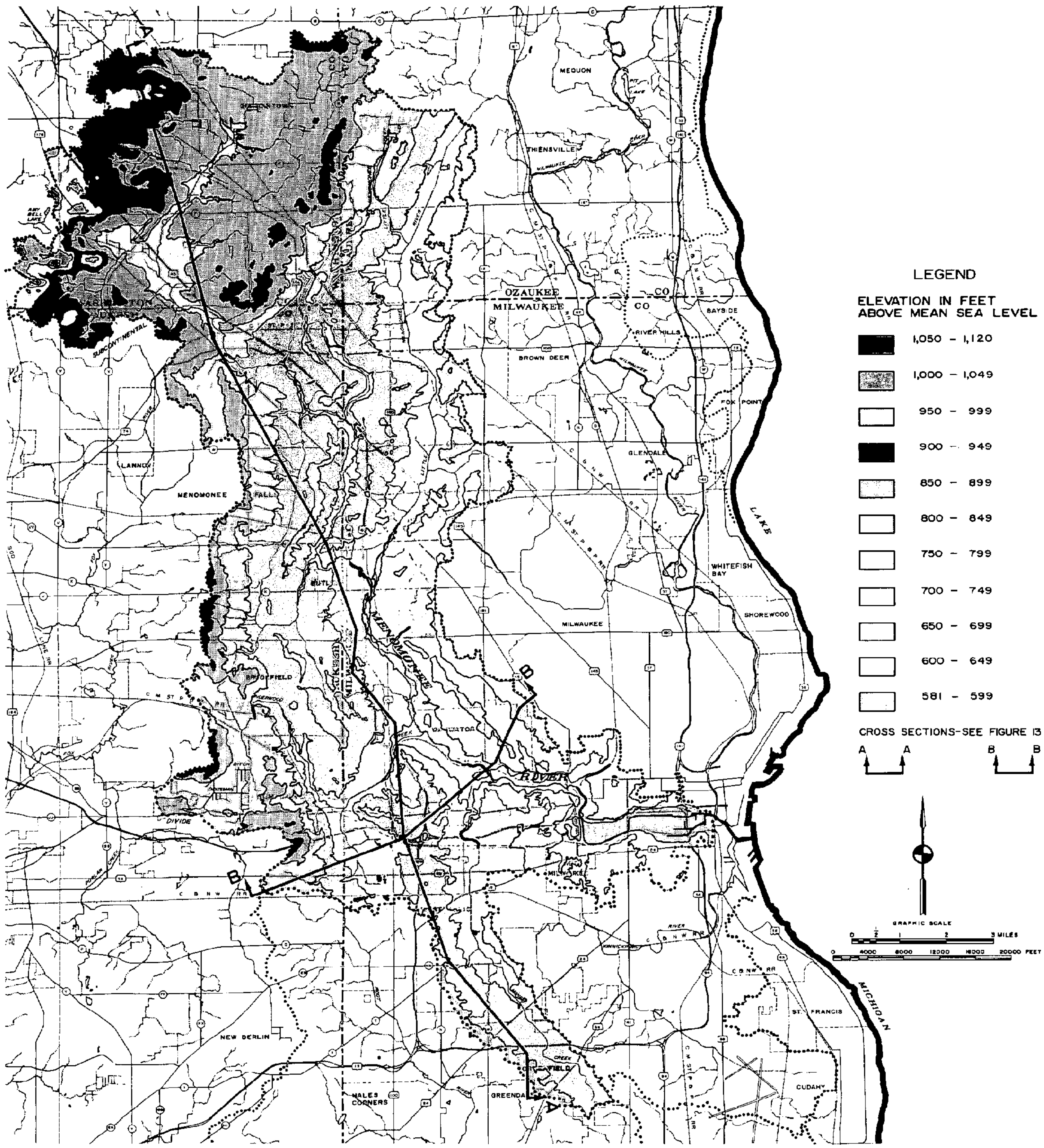


[a] BASED ON MILWAUKEE SKY COVER DATA. THESE MONTHLY DATA ARE SIMILAR TO THOSE OBSERVED AT MADISON AND AT GREEN BAY, WHICH SUGGESTS THAT THERE IS VERY LITTLE VARIATION IN THIS MONTHLY DATA FOR THE LARGE GEOGRAPHIC REGION, RELATIVE TO THE MENOMONEE RIVER WATERSHED, REPRESENTED BY THESE THREE NATIONAL WEATHER SERVICE STATIONS. THEREFORE, THE MILWAUKEE DAYLIGHT AND SKY COVER MONTHLY DATA MAY BE CONSIDERED APPLICABLE TO THE WATERSHED. SKY COVER CONSISTS OF CLOUDS OR OBSCURRING PHENOMENA, AND IS EXPRESSED IN TENTHS. A DAY IS CLASSIFIED AS CLEAR IF THE SKY COVER DURING THE DAYLIGHT PERIOD IS 0-0.3, PARTLY CLOUDY IF THE SKY COVER IS 0.4-0.7, AND CLOUDY IF THE SKY COVER IS 0.8-1.0. MONTHLY SKY COVER INDICATES, BY MONTH, THE PERCENT OF DAYS THAT HISTORICALLY HAVE BEEN CLEAR, PARTLY CLOUDY, OR CLOUDY.

Source: Adapted by SEWRPC from National Weather Service and U. S. Naval Observatory data.

Map 15

TOPOGRAPHIC CHARACTERISTICS OF THE MENOMONEE RIVER WATERSHED

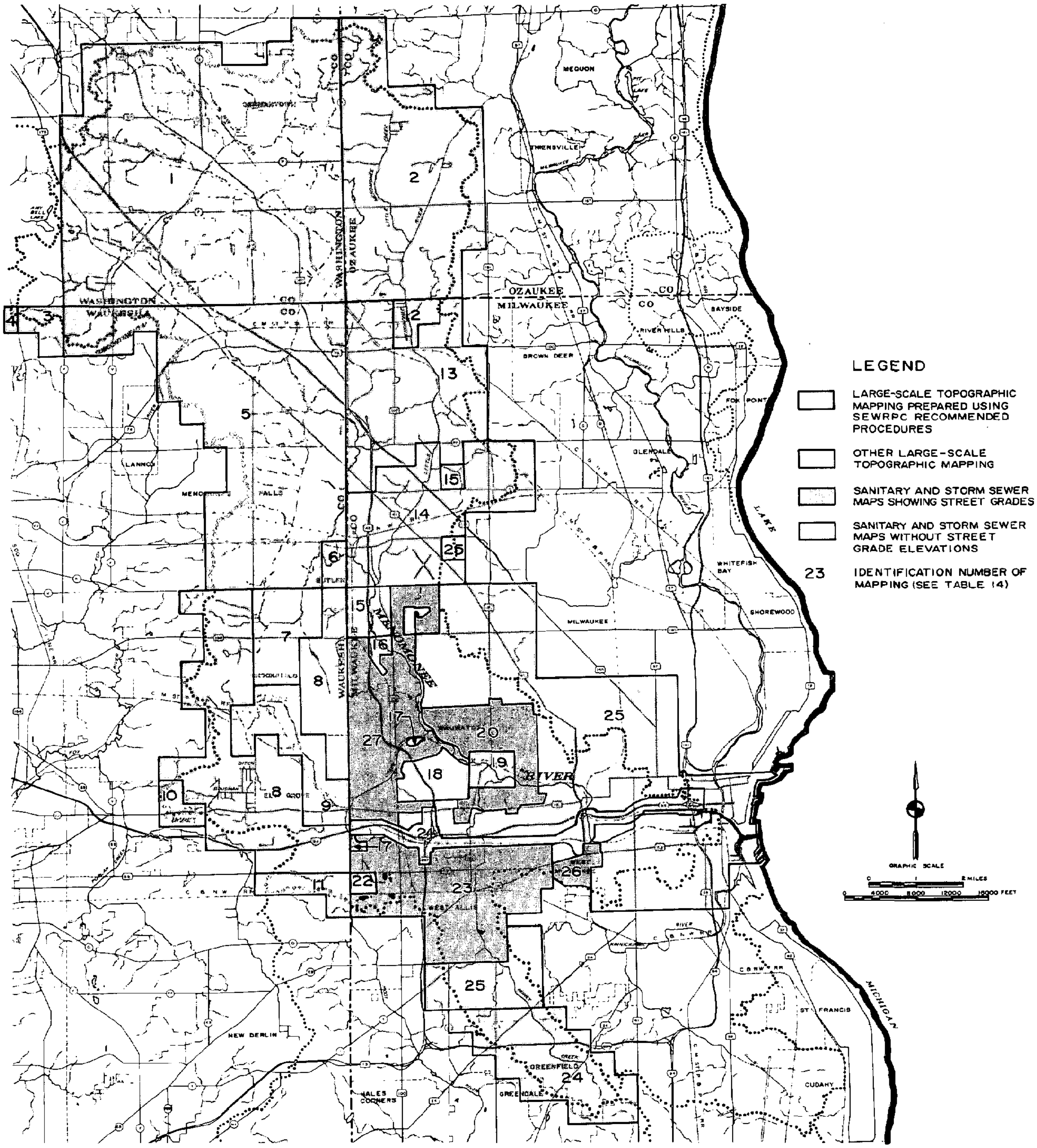


Glacial deposits superimposed on underlying bedrock establish the overall topography of the Menomonee River watershed. The watershed surface generally slopes downward from west to east, with the eastern edge of the basin lying 150 to 300 feet below the western edge. Ground elevations in the watershed range from a high of approximately 1,120 feet above sea level in the Town of Richfield, Washington County, to a low of approximately 580 feet above sea level in the Menomonee River industrial valley—a maximum relief of 540 feet. The dominant physiographic feature of the basin is a rolling to gently sloping ground moraine composed of heterogeneous material deposited beneath the several ice sheets that advanced over and receded from the watershed in ages past.

Source: SEWRPC.

Map 16

AVAILABILITY OF LARGE-SCALE MAPPING IN THE MENOMONEE RIVER WATERSHED: 1975



Some type of large-scale mapping is available for about 135 square miles, or about 98 percent, of the Menomonee River watershed. Of that total, large-scale topographic maps prepared using SEWRPC recommended procedures are available for about 56 square miles, or about 42 percent of the watershed area. Included in the 56 square mile total are 3.25 square miles of large-scale topographic maps prepared specifically for the Menomonee River watershed planning program. The large-scale mapping was used in a variety of ways during the preparation of the watershed plan, including providing input to the hydrologic-hydraulic simulation modeling effort and selecting sites and routes for alternative water-related public facilities and utilities. The extensive amount of available large-scale mapping will also be valuable during the plan implementation process.

Source: SEWRPC.

Table 14

SELECTED INFORMATION PERTAINING TO LARGE-SCALE MAPPING IN THE MENOMONEE RIVER WATERSHED: 1975

Identification Number on Map 16	Civil Division		Scale		Contour Interval (feet)	Mapping Prepared Using SEWRPC Recommended Procedures[a]	Mapping Agency or Firm	Agency or Community For Which Mapping Was Originally Prepared	Date of Photography or Field Work	Date of Map Preparation
	County	City, Village, or Town	Original Compilation	Reduction						
1	Washington	Village and Town of Germantown	1" = 100'	--	2	Yes	Alster & Associates, Inc.	Village of Germantown	1964	1964
2	Ozaukee	City of Mequon	1" = 200'	--	5	No	Nelson Ball & Associates	City of Mequon	1960	1960
3	Waukesha	Town of Lisbon	1" = 200'	--	5	No	Abrams Aerial Survey Corp.	Waukesha County Park and Planning Commission	1960	1962
4	Waukesha	Town of Lisbon	1" = 200'	--	5	No	Abrams Aerial Survey Corp.	Waukesha County Park and Planning Commission	1961	1963
5	Waukesha	Village of Menomonee Falls	1" = 100'	1" = 200'	2	Yes	Alster & Associates, Inc.	Village of Menomonee Falls	1966	1967
6	Waukesha	Village of Butler	1" = 100'	--	2	Yes	Alster & Associates, Inc.	Wisconsin Department of Transportation, Division of Highways	1966	1967
7[b]	Waukesha	City of Brookfield	1" = 200'	--	2	Yes	Alster & Associates, Inc.	City of Brookfield	1975	1975
8	Waukesha	Villages of Butler and Elm Grove and City and Town of Brookfield	1" = 200'	--	5	No	Abrams Aerial Survey Corp.	Waukesha County Park and Planning Commission	1956	1956
9	Waukesha	Village of Elm Grove	1" = 200'	--	2	Yes	Alster & Associates, Inc.	SEWRPC	1972	1974
10	Waukesha	City and Town of Brookfield	1" = 100'	1" = 200'	2	Yes	Alster & Associates, Inc.	SEWRPC	1967	1968
11	Waukesha	City of New Berlin	1" = 100'	--	2	Yes	Alster & Associates, Inc.	City of New Berlin	1965	1968
12	Milwaukee	City of Milwaukee	1" = 50'	--	1	No	Milwaukee County Department of Public Works, Architect and Engineering Division	Milwaukee County Park Commission	1970	1970
13	Milwaukee	City of Milwaukee	1" = 100'	--	2	No	Abrams Aerial Survey Corp.	City of Milwaukee, Bureau of Engineering	1962	1962
14	Milwaukee	City of Milwaukee	1" = 100'	--	2	No	Abrams Aerial Survey Corp.	City of Milwaukee, Bureau of Engineering	1956	1957
15	Milwaukee	Cities of Milwaukee and Wauwatosa	1" = 200'	--	5	No	Chicago Aerial Survey	Milwaukee County Park Commission	1966	1966
16	Milwaukee	City of Wauwatosa	1" = 100'	--	1	No	Milwaukee County Department of Public Works, Engineering Division	Milwaukee County Park Commission	1966	1966
17	Milwaukee	Cities of Wauwatosa and West Allis	1" = 50'	--	1	No	National Survey Service	Milwaukee County Park Commission	1966	1966
18	Milwaukee	City of Wauwatosa	1" = 50'	1" = 200'	1	No	Alster and Associates, Inc.	Milwaukee County Institutions	1969	1969
19	Milwaukee	City of Wauwatosa	1" = 100'	--	2	No	Abrams Aerial Survey Corp.	City of Wauwatosa	1954	1960
20	Milwaukee	City of Wauwatosa	1" = 200'	--	--	No	City of Wauwatosa, Engineering Department	City of Wauwatosa, Engineering Department	1940	1940
21	Milwaukee	Cities of Milwaukee, Wauwatosa, and West Allis and Village of West Milwaukee	1" = 50'	1" = 100'	2	No	Wisconsin Department of Transportation, Division of Highways, Engineering Services Section	Milwaukee County Department of Public Works	1969	1970
22	Milwaukee	City of West Allis	1" = 50'	--	1	No	Alster & Associates, Inc.	Milwaukee County Park Commission	1969	1969
23	Milwaukee	City of West Allis	1" = 200'	--	--	No	City of West Allis	City of West Allis	1968	1968
24	Milwaukee	Cities of Greenfield and Milwaukee and Village of Greendale	1" = 200'	--	5	No	J. C. Zimmerman Engineering Corp.	City of Greenfield	1932,1966[c]	1966
25	Milwaukee	City of Milwaukee	1" = 200'	--	--	No	City of Milwaukee, Bureau of Engineers	City of Milwaukee, Bureau of Engineers	1968	1968
26	Milwaukee	City of West Milwaukee	1" = 150'	--	--	No	Steinhagen & Steinhagen Civil Engineers	Village of West Milwaukee	1958	1958
27	Milwaukee	City of Wauwatosa	1" = 200'[d]	--	--	No	Greenley and Hansen Engineers	City of Wauwatosa	1958	1958

[a] *SEWRPC recommended procedures are described in SEWRPC Technical Report No. 7, Horizontal and Vertical Survey Control in Southeastern Wisconsin.*

[b] *Mapping for this 2.5 square mile area was completed subsequent to the inventory phase of the Menomonee River watershed study. Mapping similar to that which is described for identification number 8 was used in the inventory phase.*

[c] *The original topographic data were obtained in 1932 and this was supplemented with storm and sanitary sewer system information in 1966.*

[d] *The storm sewer system mapping with street grade elevations for this area was made available after the inventory phase of the Menomonee River watershed study. Storm sewer system mapping without street grade elevations at a scale of 1" = 1200' was used in the inventory phase.*

Source: SEWRPC.

Village of Menomonee Falls. The stream is a mere thread of water as it passes through woodlands and wetlands in some of these headwater areas. Menomonee Falls is traversed in a southeasterly direction, with this reach containing some of the steepest channel grades in the watershed. The Menomonee River then turns southward as it meanders along the Waukesha-Milwaukee County line until it enters the City of Wauwatosa. From this point the Menomonee River flows southeasterly through Milwaukee County parkway lands in Wauwatosa, and after entering the City of Milwaukee, proceeds in an easterly direction in a channelized cross section to its confluence with the Milwaukee and Kinnickinnic Rivers. Several major streams, each with unique characteristics, are tributary to the Menomonee River including the Little Menomonee River, Underwood Creek, and Honey Creek.

Geology—A Stratigraphic and Historical Overview

The geology of the Menomonee River watershed is a complex system of various layers and ages of rock formations. The type and extent of the various bedrock formations underlying the watershed was determined primarily by the environments in which the sediments forming the various rock layers were deposited. The surface of this varied system of rock layers was, moreover, deeply eroded prior to being buried by a blanket of glacial deposits consisting of unconsolidated sand, silt, clay, gravel, and boulders. The bedrock formations underlying the Menomonee River watershed consist of, in ascending order, predominantly crystalline rocks of the Precambrian Era, Cambrian through Devonian Period sedimentary rocks of the Paleozoic Era, and unconsolidated surficial deposits. Only the glacial deposits and the youngest sedimentary rocks are exposed in the watershed. The subsurface stratigraphy of the Menomonee River watershed is summarized in Table 15, geologic sections through the watershed are shown in Figure 13, and the locations of these sections are shown on Map 15.

Precambrian Rock Units: Precambrian crystalline rocks thousands of feet thick form the basement on which younger rocks were deposited. Little is known of their origin, but in wells within or near the watershed that reach the Precambrian basement, the rock types include quartzite and granite. The Precambrian rocks were extensively eroded to an uneven surface before the overlying sedimentary formations were deposited. Layered sedimentary rocks overlying the Precambrian rocks consist primarily of sandstone, shale, and dolomite. These rocks were deposited during the Cambrian, Ordovician, Silurian, and Devonian geologic time periods, in seas that covered much of the present North American continent.

Cambrian Rock Units: Cambrian rocks in the watershed are primarily sandstone, but contain some siltstone, dolomite, and shale. The most dominant Cambrian rock units are the two lowermost units, the Mount Simon sandstone which was deposited on the Precambrian surface, and the Eau Claire sandstone. The two units are present throughout the watershed. The other three Cambrian rock units in the watershed—the Galesville sandstone, Franconia sandstone, and Trempealeau formation—are younger than the Mount Simon and Eau Claire sandstones, and have been found only locally in the southern portion of the basin. Most of the Galesville and Franconia sandstones and the Trempealeau formation were probably eroded and thereby removed from the watershed before deposition of the Ordovician rock units. Cambrian rocks are thickest in the Milwaukee County area, where the combined thickness of the Mount Simon and Eau Claire sandstones is probably in excess of 1,200 feet. Northward into the headwater areas of the watershed, the thickness of the Cambrian rocks is significantly reduced to about 600 feet.

Ordovician Rock Units: Ordovician rocks in the watershed consist of sandstone, dolomite, and shale. The St. Peter sandstone, which was deposited on an erosion surface cut into the underlying Cambrian formations, has a relatively uniform thickness of about 200 feet over much of the watershed except for the northern portions, where it appears too thin to less than 150 feet. The Platteville formation, Decorah formation, and Galena dolomite were deposited in succession on top of the St. Peter sandstone, but are not differentiated in the watershed. The combined thickness of these dolomitic units is generally between 200 and 300 feet. Above these is the Maquoketa shale, which has a thickness of about 200 feet throughout the watershed.

Silurian and Devonian Rock Units: Silurian rocks consisting of undifferentiated dolomite strata overlie the Maquoketa shale. They form the bedrock beneath the glacial deposits in essentially all of the watershed. The outcrops of Silurian dolomite appeared and were quarried at several localities within the watershed. Relative to most of the other rock units found in the watershed, the thickness of the Silurian dolomite exhibits marked spatial variations. Thickness ranges from a minimum of about 100 to 150 feet in the southeastern portion of the watershed and in the Village of Menomonee Falls to a maximum of over 450 feet in the City of Mequon. Large local differences in the thickness of the Silurian dolomite are probably due to preglacial and glacial erosion. Dolomitic rocks of Devonian age are known to overlie the Silurian dolomite at only three well locations in the southeastern part of the watershed.

Pleistocene and Holocene Deposits: Unconsolidated deposits of boulders, gravel, sand, silt, and clay overlie the sedimentary rocks. These were deposited during the Pleistocene age by continental glaciers that covered the Region intermittently between one million and possibly as recently as 5,000 years ago. The deposits can be classified according to their origin into till and stratified drift. Till, a heterogeneous mixture of clay, silt, sand, gravel, and boulders, was deposited from ice without the sorting action of water. Most of the watershed is overlain by till in the form of either ground moraine or end moraine. Stratified drift consists primarily of sand and gravel that was sorted and deposited as outwash by glacial meltwater. Part of the Village of Germantown in the extreme northwestern portion of the Menomonee River watershed is overlain with stratified drift. Although end moraine deposits are composed mainly of till, they may locally contain stratified drift in the form of outwash sand and gravel.

Holocene materials consist of alluvium and marsh deposits. They occur only along streams and in marshy areas, and constitute a very small fraction of the unconsolidated deposits covering the watershed land surface.

Table 16 summarizes the lithology and water-yielding characteristics of the unconsolidated deposits of the Pleistocene and Holocene ages in the Menomonee River watershed. As indicated in the table, the unconsolidated deposits are lithologically varied and generally yield only small quantities of water to wells.

Mineral and Organic Resources

Sand and gravel, dolomite building stone and crushed aggregate, and organic material are the three principal mineral and organic resources in the Menomonee River watershed that have or have had significant commercial value as a result of their quantity, quality, and location.

Table 15

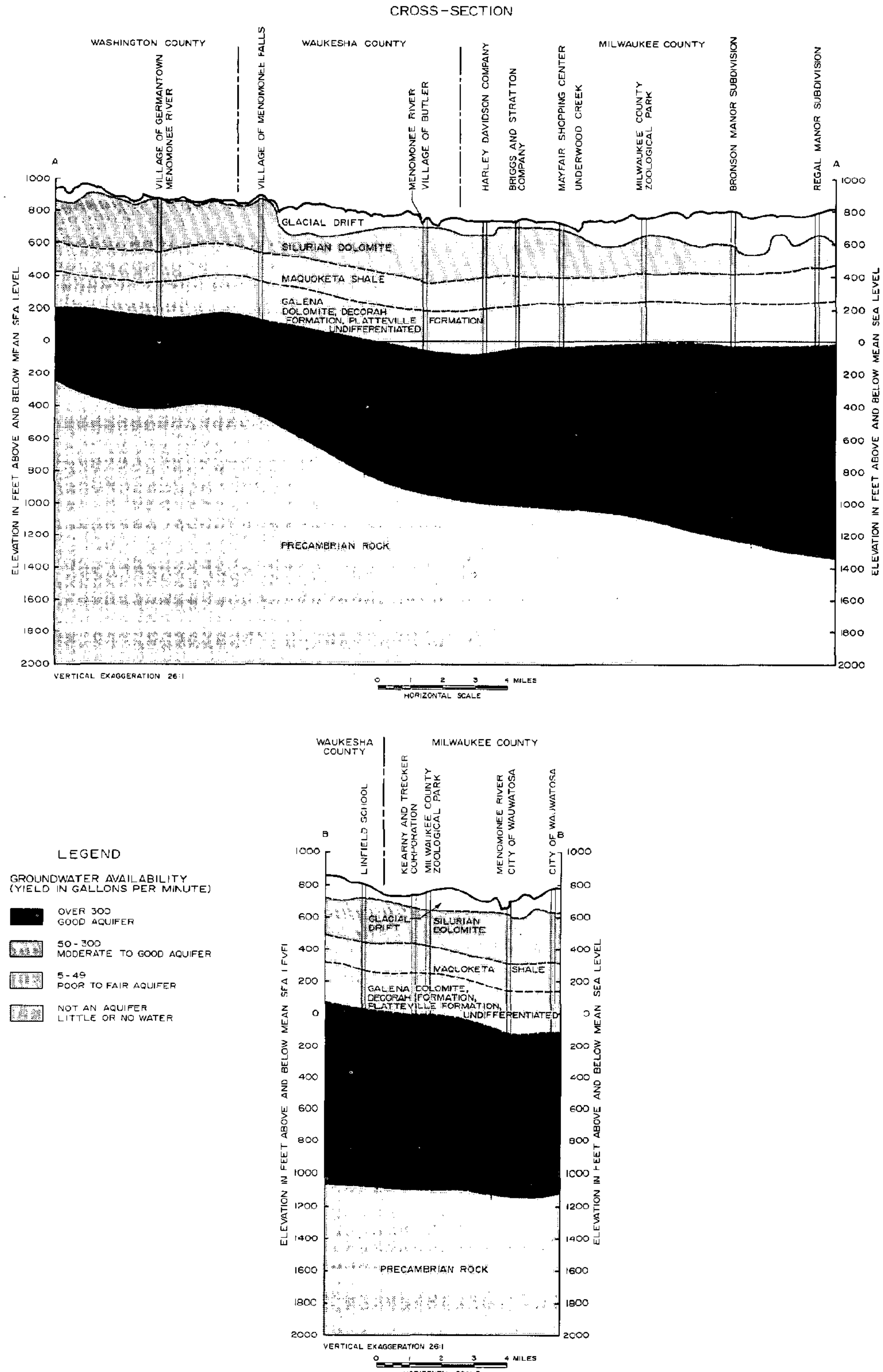
STRATIGRAPHY OF THE MENOMONEE RIVER WATERSHED

Geologic Age	Stratigraphic Unit	Thickness Range (feet)	Lithology	Areal Extent
Holocene	Alluvium and marsh deposits	0-25(?)	Peat, clay, silt, sand, and gravel.	Occurs only locally in stream, valleys, and marshes.
Pleistocene	Glacial deposits	0-280(+)	Clay, silt, sand, and gravel.	Underlies entire watershed except on rock outcrops.
Devonian	Dolomite Undifferentiated	0-35	Dolomite, thick-bedded, gray.	Recognized only in three wells in the southeastern part of the watershed.
Silurian	Dolomite Undifferentiated	45-445	Dolomite, dense, thick-bedded, light gray; some beds cherty; some coral reefs.	Underlies entire watershed.
Ordovician	Maquoketa Shale Undifferentiated	100-205	Shale, dolomitic, gray, with interbedded dolomite.	Underlies entire watershed.
	Galena Dolomite, Decorah Formation, and Platteville Formation, Undifferentiated	215-330	Dolomite, light gray to tan. Sandy dolomite or dolomitic sandstone at base.	Underlies entire watershed.
	St. Peter Sandstone	80-255	Sandstone, medium to fine grained, dolomitic, white to light gray.	Underlies entire watershed.
Cambrian	Trempealeau Formation	0-15	Sandstone, very fine to medium grained. Dolomite light gray, interbedded with siltstone in lower part.	These units are recognized only in one well in the southwest part of the watershed.
	Franconia Sandstone	0-10(+)	Sandstone, very fine to medium grained, glauconitic.	
	Galesville Sandstone	0-135	Sandstone, fine to medium grained, light gray.	Recognized only in two wells in southern part of watershed.
	Eau Claire Sandstone	115-340	Sandstone, very fine to medium grained. Dolomitic and shale.	These units underlie entire watershed.
	Mount Simon Sandstone	255-1,700+(?)	Sandstone, fine to coarse grained, white or light gray. Some interbedded thin shale.	
Precambrian	Undifferentiated	(Thousands of feet)	Crystalline rocks including granite and quartzite.	Underlies entire watershed.

Source: U. S. Geological Survey.

Figure 13

STRATIGRAPHIC CROSS SECTIONS THROUGH THE MENOMONEE RIVER WATERSHED SHOWING THE GENERAL AVAILABILITY OF GROUNDWATER FROM THE BEDROCK UNITS



Source: U. S. Geological Survey.

Table 16

LITHOLOGY AND WATER-YIELDING CHARACTERISTICS OF THE UNCONSOLIDATED DEPOSITS OF PLEISTOCENE AND HOLOCENE AGES IN THE MENOMONEE RIVER WATERSHED

Unit	General Description	Water-Yielding Characteristics
Organic deposits	Peat and muck	Generally saturated; not used as a source of water for wells
Stream alluvium	Clay, silt, and sand; sorted and stratified	Generally saturated but too thin to be a source of water for wells
Buried outwash	Mostly sand and gravel, sorted and stratified, lying within or beneath glacial till	Yield small to moderate quantities of water
Ice-contact deposits . . .	Clay, silt, sand, gravel, and boulders; unstratified to stratified and unsorted to sorted	Yield small quantities of water; upper part commonly unsaturated
Glacial till	Clay, silt, sand, gravel, and boulders; unsorted and unstratified	Permeability low to very low; not used as a source of water for wells

Source: U. S. Geological Survey.

The commercial utilization of the watershed's mineral resources, which is limited to the mining of nonmetal deposits, is primarily directed toward supplying the construction materials needed for the continuing development of the Menomonee River watershed and adjacent areas.

Sand and Gravel Pits and Dolomite Quarries: The Region as a whole has an abundant supply of natural sand and gravel deposits as a result of its glacial history (there are many active and semiactive sand and gravel pits in southeastern Wisconsin), with the highest quality deposits being found in glacial outwash areas, particularly near the interlobate Kettle Moraine, where the washing action of flowing meltwaters has sorted the unconsolidated material so as to form more or less homogeneous, and therefore commercially attractive, deposits. Active sand and gravel pits are defined as those at which mining and related equipment was present and operating in 1974, whereas semiactive pits are those not having operating equipment but at which there was definite evidence of recent mining or stockpiling activities. There are four active or semiactive sand and gravel pits within the Menomonee River watershed as shown on Map 17. Equally significant are the 23 inactive sand and gravel pits and dolomite quarries in the watershed also shown on Map 17. Inactive sand and gravel pits are those exhibiting no evidence of current or recent mining or mining related activities.

Sand and gravel deposits are important sources of concrete aggregate, gravel for road subgrade and surfacing, sand for mortar, and molding sand. Depending on the nature of the deposits, particularly their depth and areal extent, grain size of the particles, and depth to the water table, sand and gravel deposits may seriously hamper tunneling, trenching, and excavation work. Therefore, detailed field investigations should be conducted in areas of known or expected deposits prior to initiation of public utility and other public and private construction activities.

Silurian dolomite, which lies immediately below the glacial deposits throughout most of southeastern Wisconsin, has commercial value when it is found relatively close to the ground surface, both as a dimensional building stone and, when crushed, as an aggregate for construction or as a fertilizer for agricultural purposes. Although it is in fact dolomite—that is, primarily calcium magnesium carbonate—the high quality dimensional building stone currently commercially mined and produced in Waukesha County is commonly known as limestone—that is, primarily calcium carbonate—or lannon stone. There are no active or semiactive dimensional stone quarries or crushed stone quarries located within the Menomonee River watershed.

Potential Uses of Abandoned Sand and Gravel Pits and Dolomite Quarries: As noted above, the Menomonee River watershed contains 23 inactive sand and gravel pits and dolomite quarries. Inactive sand and gravel deposits and dolomite quarries, and more particularly the excavations left as a result of the mining operations, have the potential to serve a variety of needs in the ever-expanding urban area. The depressions may serve initially as solid waste disposal sites, and upon filling, serve residential, commercial, or industrial land uses. Lakes and ponds developed in the depressions left by sand and gravel and dolomite operations could complement contiguous public recreational areas or private residential, commercial, or industrial development. Those depressions that are in an urban setting may also serve as storm water detention ponds. Carefully selected inactive sand and gravel pits and dolomite quarries could also be preserved, in whole or in part, as scientific sites, oriented to the study of glacial and bedrock geology, or as historic sites intended to inform visitors of the commercial activities of early inhabitants.

An example of the use of an inactive quarry as a historic site is the Village of Menomonee Falls Limestone Park along the Menomonee River, which contains portions of an abandoned quarry and protected lime kilns. Here the visitor can learn how dolomite limestone rock was burned in the kilns to convert it to lime, which was used for agricultural, constructional, and medicinal purposes.

Hartung Quarry, a large—20 acres in area and up to 130 feet deep—former source of road construction material,[5] is located immediately east of the Menomonee River Parkway between Burleigh Street and Capitol Drive on the boundary between the Cities of Milwaukee and Wauwatosa. This excavation has scientific value in that the northwest wall is noted as an excellent source of fossil forms, primarily trilobites, representing the Silurian age,[6] which ended about 320 million years ago.[7]

Organic Deposits: Organic deposits are widely distributed throughout the watershed in small, scattered, low-lying, poorly drained areas. At these locations, excessive moisture inhibits oxidation and decay of the residues of water-tolerant plants, producing organic peat deposits and muck soils with significant resulting fertilization potential. These organic deposits overlay the glacial drift of the Region and exhibit variable depths ranging from less than a foot to many feet.

Organic deposits have environmental value, often covering areas suitable for certain kinds of wildlife habitat and recreational uses, and have commercial value in their ability to support field crops such as corn or soybeans, specialized crops such as vegetables and sod farming, and peat mining, the last of which is excavated from open pits and marketed as an additive to improve soils for potted plants, gardens, and greenhouse nurseries. Agricultural use of organic deposits is contingent upon sufficient depth so that artificial drainage can be developed and maintained.

Organic deposits generally serve to identify those areas of the watershed that are least suited for extensive urbanization and attendant major construction activity. The presence of organic deposits may constitute a serious problem for the development of onsite sewage disposal systems, primarily because of the inherent moisture problem and resultant poor drainage characteristics. Organic deposits may also prevent or complicate public utility and facility construction because of the difficulty of operating heavy equipment on, and of working with, organic deposits; because of the poor foundation characteristics of such deposits; and because of the potential infiltration problems through sewer pipe joints and foundation walls attributable to the high moisture content of such deposits.

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[5] *William O. Hotchkiss and Edward Steidtmann, "Limestone Road Materials of Wisconsin," Wisconsin Geological and Natural History Survey, Bulletin No. 34, 1914, p. 65.*

[6] *Silurian trilobites are a group of marine arthropods that are now extinct.*

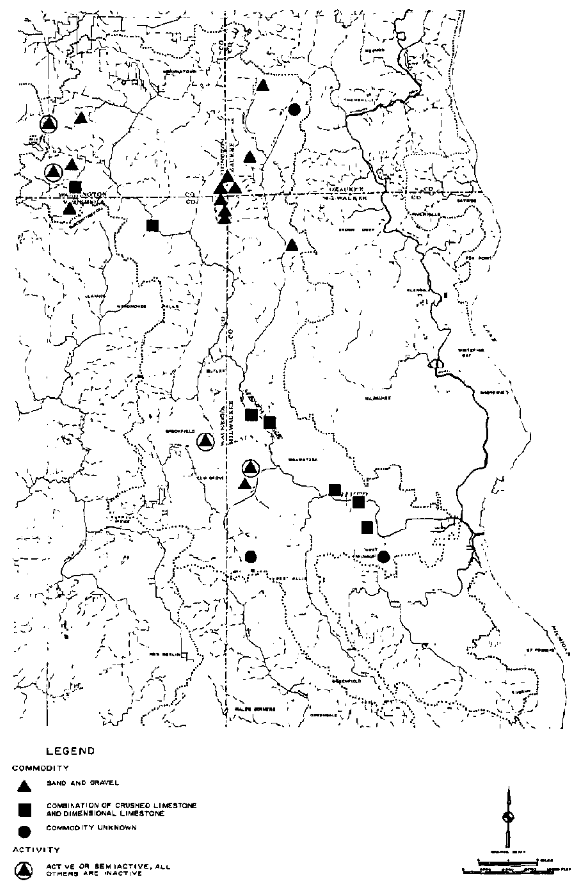
[7] *Joseph G. Emielity, Silurian Trilobites of Southeastern Wisconsin, 1963, p. 5.*

Soils

The nature of the soils within the Menomonee River watershed has been determined primarily by the interaction of the parent glacial deposits covering the Region with topography, climate, plants, animals, and time. Within each soil profile, the effects of these soil-forming factors are reflected in the transformation of soil material

Map 17

QUARRY SITES IN THE MENOMONEE RIVER WATERSHED: 1974



The most significant mineral resources mined and used in and near the Menomonee River watershed have been sand, gravel, and crushed stone. The commercial utilization of these resources has been directed primarily toward providing construction materials required by ever-expanding urban developments. There are 23 known inactive sand and gravel pits and quarries in the Menomonee River watershed. The excavations resulting from these former mining operations have the potential to satisfy a variety of needs in the urbanizing areas. For example, these depressions may serve as solid waste disposal sites, storm water detention ponds, recreational areas, and outdoor classrooms for geologic studies.

Source: SEWRPC.

in place, chemical removal of soil components by leaching or physical removal by wind or water erosion, additions by chemical precipitation or by physical deposition, and transfer of some soil components from one part of the soil profile to another.

Soil Diversity and the Regional Soil Survey: Soil forming factors, particularly topography and the nature of the parent glacial materials, exhibit wide spatial variations in southeastern Wisconsin, and therefore hundreds of different soil types have developed within the Menomonee River watershed and the Region. In order to assess the significance of these unusually diverse soil types to sound regional development, the Commission in 1963 negotiated a cooperative agreement with the U. S. Soil Conservation Service under which detailed operational soil surveys were completed for the entire Region. The results of the soil surveys have been published in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin. The regional soil survey has not only resulted in the mapping of the soils within the Region in great detail and provided data on the physical, chemical, and biological properties of the soils, but has also provided interpretations of the soil properties for planning, engineering, agricultural, and resource conservation purposes.

Findings of the Regional Soil Survey: Regional soils were mapped, their characteristics and properties as noted above were identified, and most important, the data were interpreted for engineering, agricultural, resource conservation, and urban and rural planning purposes.

Particularly important to comprehensive watershed planning are the soil suitability interpretations for specified types of urban development. These are: residential development with public sanitary sewer service, residential development without public sanitary sewer service on lots smaller than one acre in size, and residential development without public sanitary sewer service on lots one acre or larger in size. Some of the more important considerations in determining soil suitability for urban development include depth to bedrock, depth of water table, likelihood of flooding, soil permeability, and slope.

Detailed soils data are available for 115 square miles, or 85 percent of the Menomonee River watershed. The excluded area consists of the heavily urbanized easternmost portions of the watershed, for which the acquisition of soils data was determined, prior to the conduct of the soil survey, to be of little practical value. Approximately 23 square miles, or about 20 percent of the 115 square mile portion of the watershed for which soils data are available, are covered by soils which have severe or very severe limitations for residential development, even when such development is provided with public sanitary service, or more precisely, are poorly suited for residential development of any kind. The distribution of these soils is shown on Map 18. Approximately 93 square miles, or abot 81 percent of the 115 square mile portion of the watershed for which soils data are available, are covered by soils which have severe or very severe limitations for residential development without public sanitary sewer service on lots smaller than one acre in size. The distribution of these soils is shown on Map 19. Approximately 51 square miles, or about 44 percent of the 115 square mile portion of the watershed for which soils data are available, are covered by soils which have severe or very severe limitations for residential development without public sanitary sewer service on lots one acre or larger in size. The distribution of these soils is shown on Map 20. Figure 14 summarizes the soil suitability within the watershed with respect to the construction of sanitary sewerage systems and the use of onsite sewage disposal systems. It should be noted that the use suitability ratings are empirical, being based upon the performance of similar soils elsewhere for the specified uses, as well as upon such physically observed conditions as depth to water table and bedrock permeability, shrink-swell potential, bearing capability, frost heave, slope, and flood potential.

Soils are an important factor in the determination and delineation of prime agricultural lands. As of 1970, approximately 13.9 square miles, or about 10 percent of the watershed, were designated as remaining prime agricultural lands as shown on Map 21. It is important to note that, in addition to relevant soil properties such as permeability, available moisture capacity, fertility holding capacity, and erodibility, these prime agricultural areas are based upon the size and extent of the area farmed; the historical capability of the area to consistently produce better than average crop yields; and the relationship of such lands to important high-value recreational, cultural, or scientific resource areas.

The small remaining amount of prime agricultural lands within the Menomonee River watershed is being lost to urban development at a relatively rapid rate. For example, since these prime agricultural lands were first delineated by the Regional Planning Commission in 1963, about 1.8 of the 12.6 square miles of the original watershed prime agricultural lands recommended for preservation have been converted from rural to urban uses. Not only does this constitute a rapid loss rate for prime agricultural lands, but as shown on Map 21, the urbanization has occurred in the form of small clusters of residential development scattered throughout the original prime agricultural lands. Scattered urban development like this tends to fragment the remaining prime agricultural lands into small areas that are difficult to manage and therefore retain in agricultural use.

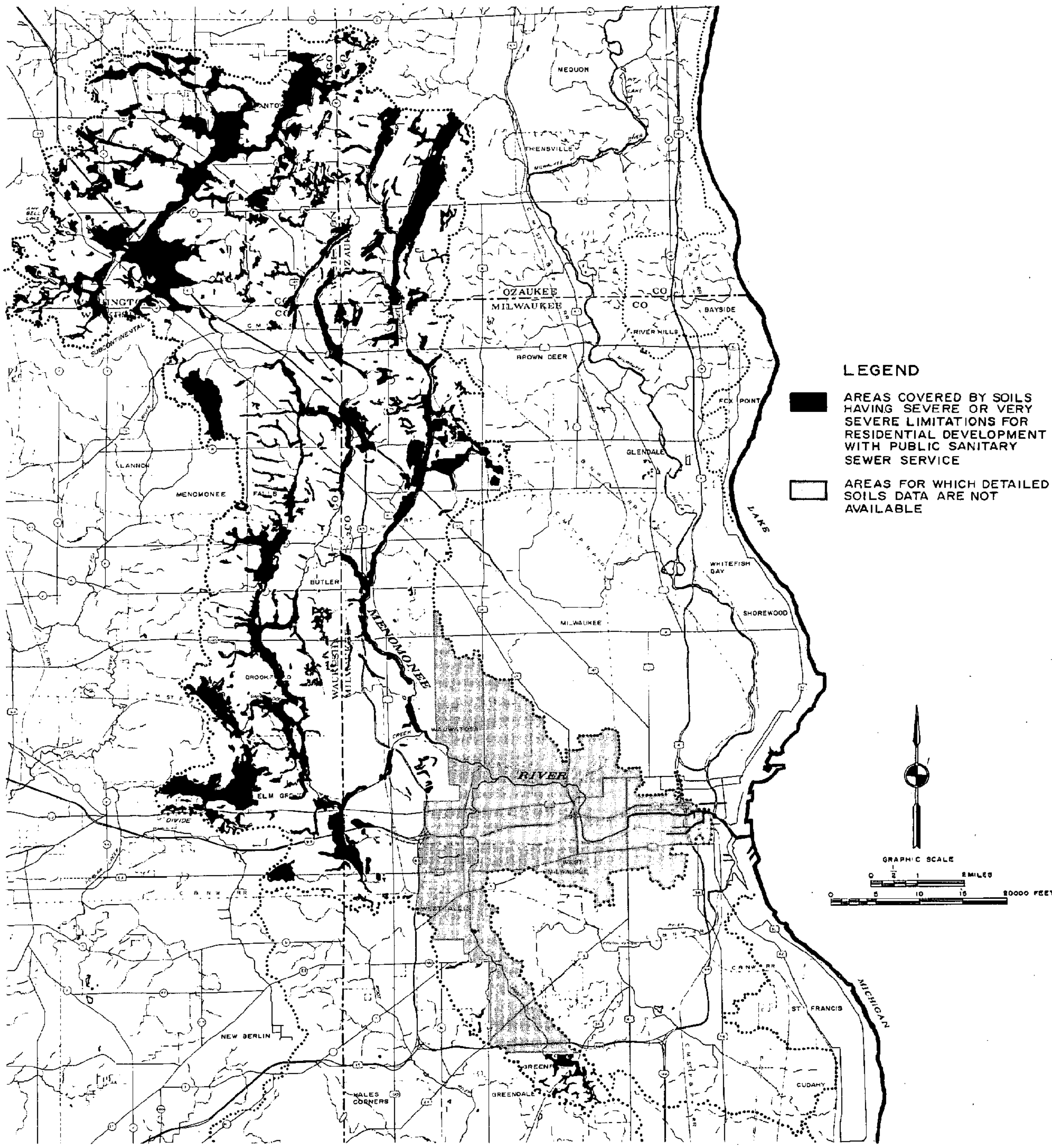
Remaining prime agricultural lands should, as recommended in the SEWRPC land use plan, be preserved for the purpose of providing food and fibre. However, unless positive action is taken to the contrary in the near future, recent urbanization will continue and the remaining agricultural lands within the Menomonee River watershed will be destroyed.

Vegetation

Watershed vegetation at any given time is determined by, or the result of, a variety of factors including climate, topography, occurrence of fire, soil characteristics, proximity of bedrock, drainage features, and, of course, the

Map 18

SUITABILITY OF SOILS IN THE MENOMONEE RIVER WATERSHED FOR RESIDENTIAL DEVELOPMENT WITH PUBLIC SANITARY SEWER SERVICE

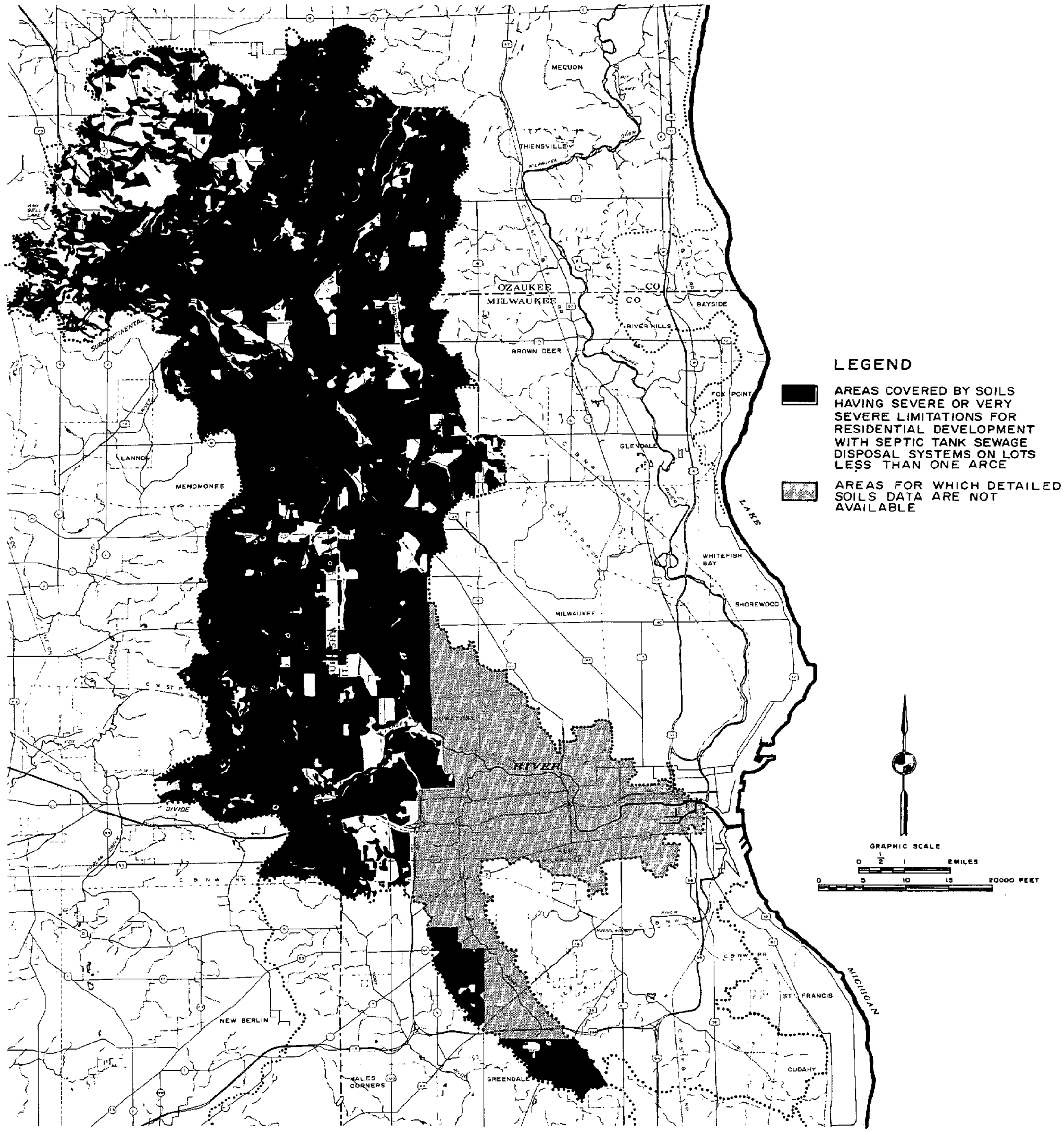


A recognition of the limitations inherent in the soil resource base is essential to the sound urban and rural development of the watershed. Approximately 23 square miles, or about 20 percent of the 115 square mile portion of the watershed for which soils data are available, are covered by soils which are poorly suited for residential development of any kind. These soils, which include wet soils having a high water table or poor drainage, organic soils which are poorly drained and provide poor foundation support, and soils which have a flood hazard, are especially prevalent in the riverine and wetland areas of the watershed.

Source: SEWRPC.

Map 19

SUITABILITY OF SOILS IN THE MENOMONEE RIVER WATERSHED FOR SMALL LOT RESIDENTIAL DEVELOPMENT WITHOUT PUBLIC SANITARY SEWER SERVICE

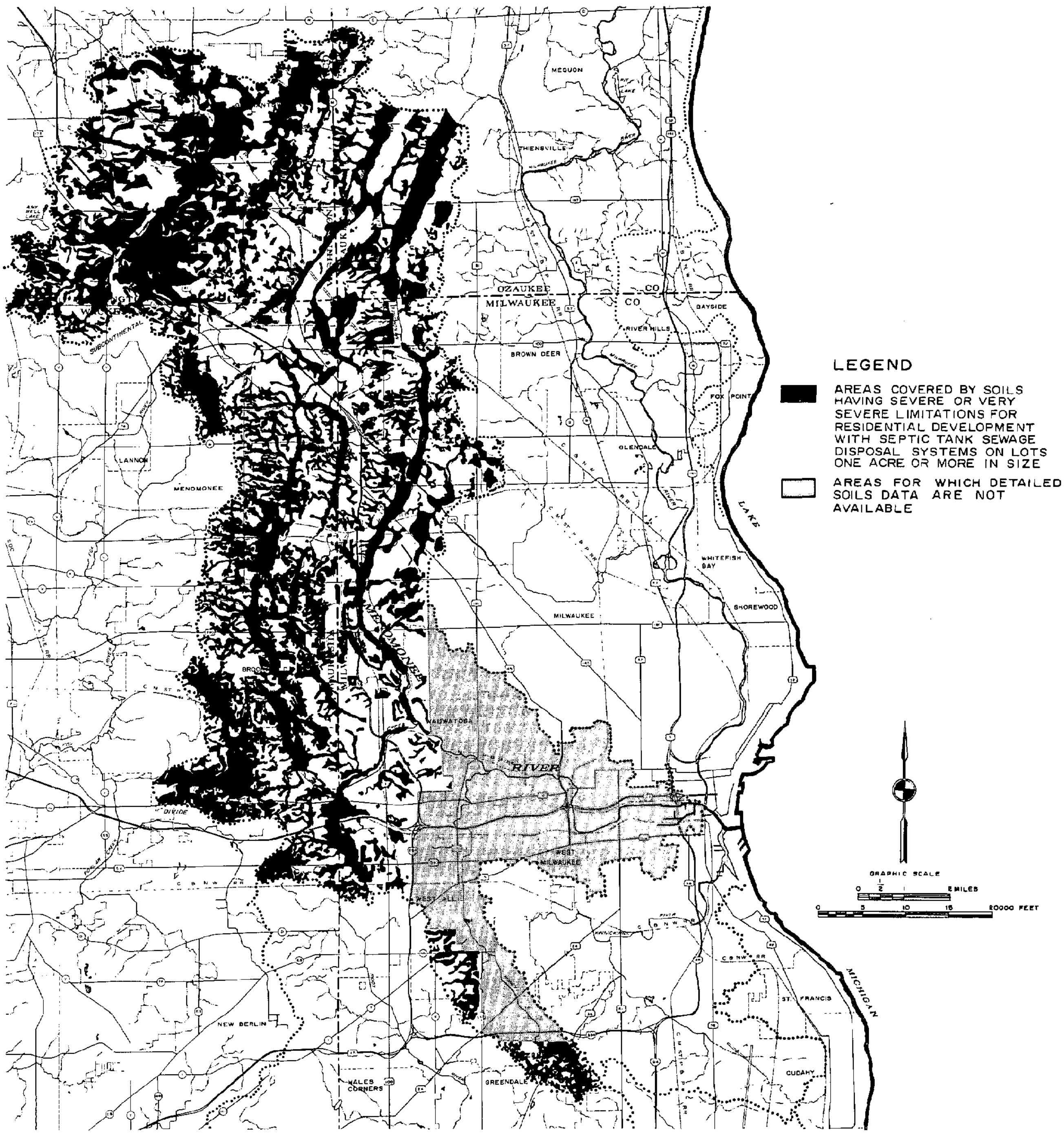


Approximately 93 square miles, or about 81 percent of the 115 square mile portion of the watershed for which soils data are available, are covered by soils poorly suited for residential development on lots having an area smaller than one acre and not served by public sanitary sewerage facilities. Reliance on septic tank sewage disposal systems in these areas, which are covered by relatively impervious soils or are subject to seasonally high water tables, may be expected to result in eventual malfunctioning of such systems and the consequent intensification of water pollution and public health problems in the watershed.

Source: SEWRPC.

Map 20

SUITABILITY OF SOILS IN THE MENOMONEE RIVER WATERSHED FOR LARGE LOT RESIDENTIAL DEVELOPMENT WITHOUT PUBLIC SANITARY SEWER SERVICE

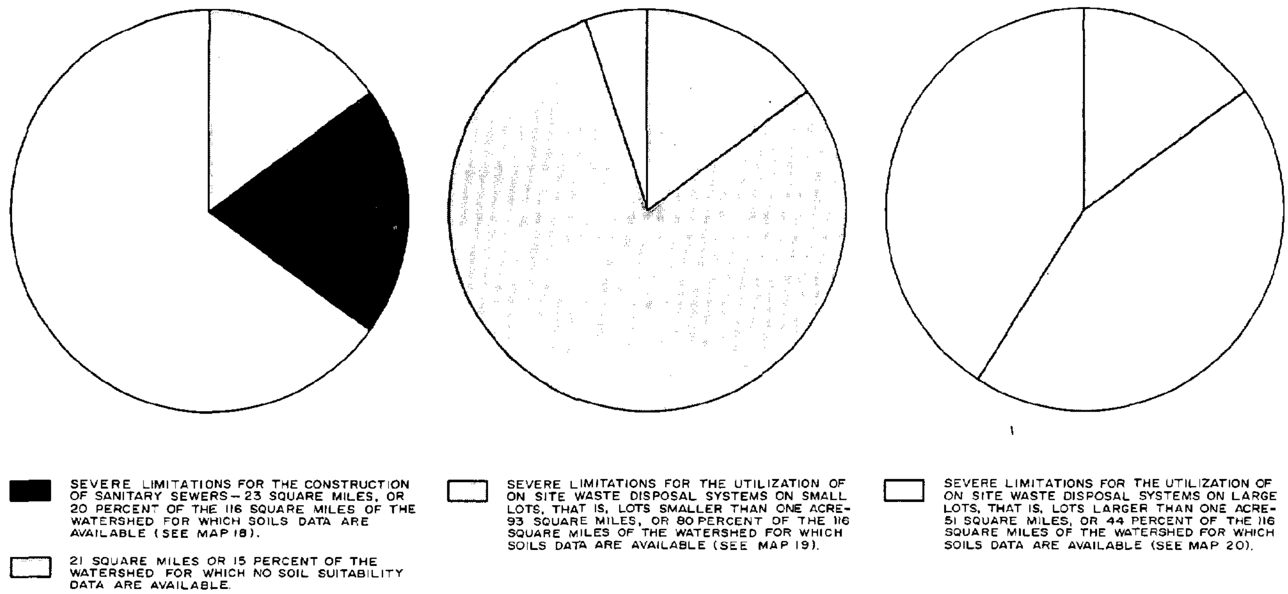


Approximately 51 square miles, or about 44 percent of the 115 square mile portion of the watershed for which soils data are available, are covered by soils poorly suited for residential development on lots having an area of one acre or more and not served by public sanitary sewerage facilities. The inherent limitations for septic tank sewage disposal systems cannot always be overcome by the provision of larger lots, since certain soil types simply cannot absorb the sewage effluent, resulting in surface ponding and runoff of partially treated wastes into nearby watercourses.

Source: SEWRPC.

Figure 14

RATING OF SOIL SUITABILITY WITH RESPECT TO SEWERAGE SYSTEMS IN THE MENOMONEE RIVER WATERSHED



Source: SEWRPC.

activities of man. Due to the temporal and spatial variability of these influencing factors and the sensitivity of vegetation to most of them, the watershed's vegetation has been a changing mosaic of different types.

The terrestrial vegetation in the watershed occupies sites which may be subdivided into two broad land classifications: wetland and woodland. Wetlands are defined as those lands which are wholly or partially covered with hydrophytic plants and wet and spongy organic soils, and which are generally covered with shallow standing water, intermittently inundated, or have a high water table. Woodlands are defined as lands at least 20 acres in area which are covered by a dense, concentrated stand of trees and associated undergrowth.

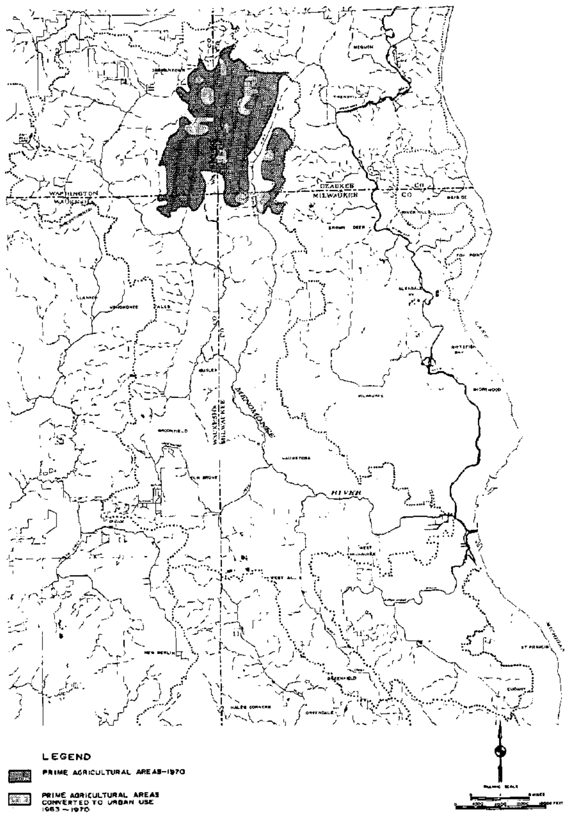
The location, extent, type, and quality of wetland and woodland areas are key determinants of the watershed's environmental quality. Such areas can, for example, support a variety of outdoor recreational activities. They offer aesthetic values, including a contribution to the beauty and visual diversity of the environment and the potential for functioning as visual and acoustic shields or barriers. Such areas and the vegetation contained within them serve important ecological functions, since they are typically on a unit area basis, the biologically most productive areas of the watershed; provide continuous wildlife range and sanctuary for native biota; and help to maintain surface water quality by functioning as sediment and nutrient traps. Finally, certain woodland and wetland areas can be excellent outdoor laboratories for educational and research activities.

Presettlement Woodlands and Wetlands: Prior to the arrival of European settlers, the vegetation of the watershed was predominantly a medium wet, or mesic, forest composed of a variety of upland deciduous hardwoods such as maple, beech, basswood, ironwood, red oak, and slippery elm. Wetter conditions prevailed in floodlands, old glacial lake beds, and other poorly drained low areas. Tamarack, black ash, or shrubs dominated the wetter areas, while silver maple and American elm grew in seasonally flooded sites. Depending on the susceptibility of certain wetlands to fire, portions of them may have been maintained as open marshes dominated by cattails, grasses, and sedges. At least part of the Tamarack Swamp—located entirely in the Village of Menomonee Falls and partly in the Menomonee River watershed—was open marsh at the time of the original land survey, while other portions were timbered with tamarack, black ash, and alder.

Historical records, including those resulting from the original U. S. Public Land Survey carried out within the watershed in 1836, provide information and insight into presettlement vegetation characteristics. For example, a land surveyor's field book contains the following description of Township 9 North, Range 20 East—the watershed portion of which now contains the Village and Town of Germantown: "This township is one-third swamp consisting of tamarack, black alder and open marsh and cedar swamp. The dry land rolling, second rate. Watercourses gravelly, sluggish. Stones are mostly limestone in small ledges in many places in the township. Timber sugar, lynn, beech, white oak, red oak, elm and black ash."

Map 21

PRIME AGRICULTURAL AREAS IN THE MENOMONEE RIVER WATERSHED: 1970



As of 1970, remaining prime agricultural areas covered only about 14 square miles, or 10 percent of the watershed. The small amount of remaining prime agricultural land is rapidly being lost to or fragmented by urbanization. The Commission's land use plan recommends that most of the remaining prime agricultural lands within the Region be retained in agricultural use to supply food, to contribute to the diversity and balance in the watershed ecological system, and to provide open space which gives form and structure to urban development.

Source: SEWRPC.

Those notes also provide the following description of Township 7 North, Range 20 East—the watershed portion of which now includes the Village of Elm Grove and the City and Town of Brookfield: "This township nearly half swamp and open marsh, the other half rolling second rate land. Soil clay, gravel loam. The southwest part large oak opening, the other part well'timbered. Timber white oak, red oak, bur oak, sugar, lynn, elm, black ash, tamarack, beech. Undergrowth hazel, haw, ironwood, grape vines, prickly ash and blackberry."

Based primarily on these and other U. S. Public Land Survey records, presettlement vegetation consisted of the following eight terrestrial plant community types, with the first two types encompassing about 95 percent of the watershed area:

1. Mesic upland hardwood forest similar to the Harley-Davidson woods in the northwest corner of the City of Wauwatosa.

2. Floodland hardwood forest containing elm, silver maple, and ash like that still in existence along the upper reaches of the Little Menomonee River in the City of Mequon.

3. Small lowland zones of tamarack swamp wetland that are similar to that which still exists near the watershed divide in the Village of Menomonee Falls in that portion of the Tamarack Swamp that lies immediately outside of the watershed.

4. Small lowland zones of open marsh wetland like that still found in the in-watershed portion of the Tamarack Swamp.

5. Small lowland area of shrub wetland containing speckled alder, winterberry, and other shrubs similar to that still found in the Tamarack Swamp.

6. Dry upland forest as indicated by the presence of the more xeric, or dry, oaks, including bur and white oaks like the remnants still remaining in Bishops Woods in the City of Brookfield. The dry upland forests in the watershed may have been former oak openings or forests on thin soils or dry slopes.

7. Transitional swamp forest elements such as those found in Germantown Swamp located in the northeast corner of the Village of Germantown, dominated by the usual silver maples and elms, with the less common yellow birch and scattered white cedars as codominants.

8. Southern swamp forest elements, such as found in the Brookfield Swamp located near the watershed divide in the City of Brookfield, which include the silver maples and willows.

Mesic upland hardwood forest and dry upland forest fall within the broad category of woodlands, whereas the remaining six plant types—floodland hardwood forest, lowland zones of tamarack swamp, open marsh, or brush marsh, southern swamp forest, and transitional swamp forest—may be categorized as wetlands.

Existing Woodlands and Wetlands: Personnel of the Wisconsin Department of Natural Resources, Bureau of Research, under a cooperative agreement with the Regional Planning Commission, conducted an inventory—including onsite field inspection—of remaining, unprotected natural areas in the Menomonee River watershed in 1973. These natural areas consisted primarily of woodland, wetland, and combination woodland-wetland areas. The results of the woodland-wetland survey are summarized below, while a detailed discussion is presented in Chapter IX of this volume.

A total of 22 woodland-wetland areas not already protected by public ownership covering 4.3 square miles, or about 3 percent of the watershed, were identified and rated as shown on Map 22. Based on the current condition, each woodland-wetland area was categorized into one of the following four value ratings:

1. High quality area—outstanding natural plant communities exhibiting minimal disturbance and containing desirable complementary natural features. The vegetal and other natural characteristics in combination with the size are such that the area is of state scientific area quality as a natural area. Bishops Woods in the City of Brookfield before its development as a commercial area exemplified a high quality natural area.

2. Good quality area—good natural plant communities and other desirable natural features with some disturbance due to logging, grazing, and water level changes. The vegetal and other natural characteristics in combination with the size are such that the area is of regional or county significance as a natural area.

3. Moderate quality area of parkway significance—the natural plant community has been significantly disturbed and few desirable complementary natural features remain. The most distinctive feature of woodland-wetland areas in this category is their riverine location, which results in a continuous, linear pattern on the landscape. Flood hazards and soils limitations in such areas mitigate against the use of these areas for urban development, whereas the remaining vegetation and other natural features give these areas potential for parkway development. Woodland-wetland areas along the Little Menomonee River in the City of Mequon exemplify moderate quality areas having parkway potential.

4. Moderate quality area of local significance—the vegetal and natural features are similar to the preceding quality category in that the natural plant community has been significantly disturbed. In contrast with the preceding category, however, these woodland-wetland sites are small and discontinuous and not necessarily located in riverine areas. The remaining natural vegetation and other natural features in these areas give them the potential for use as local natural areas and outdoor classrooms and to meet other open space needs of the urban environment. The Brookfield Swamp in the City of Brookfield is typical of a moderate quality area of local significance.

In addition to the value rating categorization, the woodland-wetland areas in the Menomonee River watershed were classified in accordance with the dominant type or types of vegetation present in such areas. The eight categories used above to describe presettlement vegetation were used to classify the existing vegetation, since the watershed contains at least remnants of all presettlement vegetation types. Based on the vegetation classification, the floodland hardwood forest is the most dominant type of vegetation.

Map 22 indicates that essentially all of the remaining unprotected woodland-wetland areas in the watershed are located either in headwater portions of the basin or along the western edge. Most of the woodland-wetland areas are in the lowest two categories, since 15 sites, or 68 percent of the total, are classified as being of only moderate quality. A total of six woodland-wetland areas—27 percent of the total—are in the good quality category. Only one high quality woodland-wetland area—Bishops Woods[8] in the City of Brookfield—exists in the watershed. In summary, only small remnants of the extensive and diverse woodland-wetland areas that were present in the watershed in presettlement times remain.

Water Resources

Surface water resources, consisting of streams and associated floodlands, form the singularly most important element of the natural resource base of the watershed. Their contribution to the economic development, recreational activity, and aesthetic quality of the watershed is immeasurable. The groundwater resources of the Menomonee River watershed are hydraulically connected to the surface water resources, inasmuch as they sustain lake levels and provide the base flow of streams. The groundwater resources along with Lake Michigan constitute the major sources of supply for domestic, municipal, and industrial water users. Indeed, the protection, enhancement, and proper development of these invaluable water resources constitute the basis for mounting the Menomonee River watershed study.

Surface Water Resources:

Lakes: None of the 100 major lakes—that is, lakes 50 acres or more in surface area—in southeastern Wisconsin is located in the Menomonee River watershed. The absence in the heavily populated Menomonee River watershed of lakes capable of supporting reasonable recreational use with little degradation of the resource is significant in that it means that recreational pressures will be more heavily exerted on the watershed stream system and on streams and lakes in adjacent watersheds.

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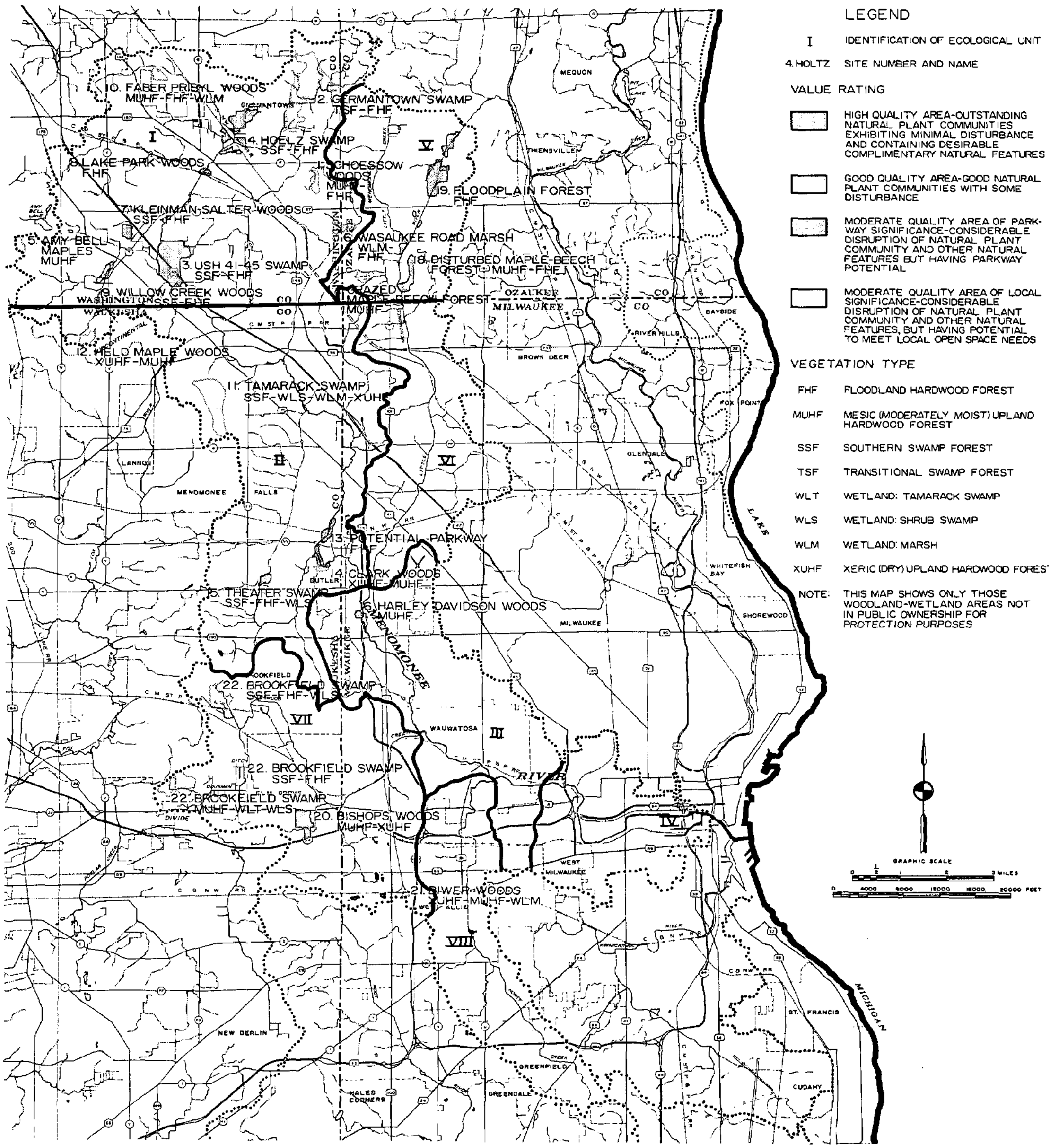
[8] *As a result of an office park development subsequent to the 1973 field survey of watershed woodlands and wetlands, Bishops Woods has been significantly disturbed and reduced in size. The remaining, essentially undisturbed portions of Bishops Woods are now classified as being of good quality; therefore, no high quality woodland-wetland areas remain in the Menomonee River watershed.*

Map 22

WOODLANDS AND WETLANDS IN THE MENOMONEE RIVER WATERSHED: 1973



A watershed's environmental quality is partly dependent on the location, extent, type, and quality of its wetland and woodland areas. Such natural areas constitute a valuable recreational resource, they are biologically productive and provide continuous wildlife range and sanctuary for native biota, and they help to maintain surface water quality by functioning as sediment and nutrient traps. Certain woodland-wetland areas can be effective outdoor laboratories for educational and research activities. Finally, woodland and wetland areas have considerable aesthetic value in an urban environment in that they contribute to the beauty and diversity of the urban areas, and have the potential to function as visual and acoustic shields or barriers. An inventory of woodland-wetland areas not already protected by public ownership revealed the existence of 22 such sites covering only 2 percent of the watershed area. It is apparent, therefore, that only small remnants of the extensive woodland-wetland areas that were present in the watershed is presettlement times remain.

Source: SEWRPC.

There are 14 minor lakes within the watershed, each having a surface water area of less than 50 acres. These minor lakes have a combined surface water area of only 33 acres and 4.1 miles of shoreline. These minor lakes generally have few riparian owners and only marginal fisheries. In most cases the value of the minor lakes is largely aesthetic.

Streams: One of the most interesting, variable, and occasionally unpredictable features of the watershed is its river and stream system with its ever changing, sometimes widely fluctuating, discharges and stages. The stream system of the watershed receives a relatively uniform flow of water from the shallow groundwater reservoir underlying the watershed. This groundwater discharge constitutes the baseflow of the streams. The streams also periodically receive surface water runoff from rainfall and snowmelt, which runoff, superimposed on the baseflow, sometimes causes the streams to leave their channels and occupy the adjacent floodplains. The volume of water drained annually from the watershed by the stream system is equivalent to about eight inches of water spread over the watershed, amounting to about one-fourth of the average annual precipitation.

Perennial streams are defined herein as those streams which maintain at least a small continuous flow throughout the year except under usual drought conditions. Within the watershed there are 68.6 lineal miles of such perennial streams, as listed in Table 17. The study of these perennial streams, plus selected reaches of intermittent streams within the watershed, comprises an important element of the watershed planning effort, and subsequent chapters of this report will develop and describe the important interrelationships existing between the stream system and other natural and man-made elements of the watershed.

Floodlands: The natural floodplain of a river is a wide, flat to gently sloping area contiguous with and usually lying on both sides of the channel. The floodplain, which is normally bounded on its outer edges by higher topography, is gradually formed over a long period of time by the river during flood stage as that river meanders in the floodplain, continuously eroding material from concave banks of meander loops while depositing it on the convex banks. A river or stream may be expected to occupy and flow on its floodplain on the average of approximately once every two years, and therefore the floodplain should be considered as an integral part of a natural stream system.

How much of the natural floodplain will be occupied by any given flood will depend upon the severity of that flood, and more particularly, upon its elevation or stage. Thus, an infinite number of outer limits of the natural floodplain may be delineated, each related to a specified flood recurrence interval. The Southeastern Wisconsin Regional Planning Commission recommends, therefore, that the natural floodplains of a river or stream be more specifically defined as those corresponding to a flood having a recurrence interval of 100 years, with the natural floodlands being defined as consisting of the river channel plus the 100-year floodplain.

Table 17

PERENNIAL STREAMS IN THE MENOMONEE RIVER WATERSHED

Perennial Stream	Tributary To:	Upstream End	Length[a] (miles)	County or Counties in Which Stream is Located
Menomonee River	Milwaukee River	Chicago & Northwestern Railroad	27.91	Milwaukee, Washington, and Waukesha
Little Menomonee River	Menomonee River	Sunnyvale Road extended	9.65	Milwaukee and Ozaukee
Honey Creek	Menomonee River	S. 43rd Street	8.86	Milwaukee
Underwood Creek	Menomonee River	Calhoun Road (CTH KX)	8.14	Milwaukee and Waukesha
Butler Ditch	Menomonee River	0.15 mile north of Lisbon Road (CTH K)	3.60	Waukesha
Dousman Ditch	Underwood Creek	Calhoun Road (CTH KX)	2.56	Waukesha
Little Menomonee Creek	Little Menomonee River	0.2 mile north of Freistadt Road (CTH F)	2.48	Ozaukee
West Branch Menomonee River . . .	Menomonee River	Private Drive	1.78	Washington
Woods Creek	Menomonee River	S. 50th Street extended	1.09	Milwaukee
South Branch Underwood Creek. . .	Underwood Creek	W. Schlinger Avenue	1.08	Milwaukee and Waukesha
South Menomonee Canal	Menomonee River	S. 13th Street extended	0.87	Milwaukee
Burnham Canal	South Menomonee Canal	S. 15th Street extended	0.58	Milwaukee
Total	--	--	68.60	--

[a] *Total perennial stream length as shown on U. S. Geological Survey quadrangle maps.*

Source: SEWRPC.

A floodway is that designated portion of the regulatory floodlands required to convey the 100-year recurrence interval flood discharge. The floodway, which includes the channel, is that portion of the floodlands not suited for human habitation. All fill, structures, and other development that would impair floodwater conveyance by adversely increasing flood stages or velocities, or would itself be subject to flood damage, should be prohibited in the floodway.

The floodplain fringe is that portion of the regulatory floodplain lying outside of the floodway. Floodwater depths and velocities are small in this regulatory area relative to the floodway, and therefore in a developed urban area further development may be permitted, although restricted and regulated so as to minimize flood damage. Because the regulatory floodway may result in increases in the stage of the regulatory flood relative to that which would occur under natural conditions, the floodplain fringe may include at its edges areas that would not be subject to inundation under natural conditions, but would be subject to inundation under regulatory floodway conditions.

The delineation of the natural floodlands in the watershed is extremely important to sound planning and development. Because of flood hazards, high water tables, and inadequate soils, floodland areas are generally not well suited to urban development. Furthermore, the regional land use plan indicates that these floodlands are not needed for incremental urban development, that there is sufficient suitable land outside of the floodlands. Floodland areas, however, are generally prime locations for much needed park and open space areas, and contain many of the best remaining woodland, wetland, and wildlife habitat areas of the Region. The floodlands also have important floodwater conveyance and storage functions.

Therefore, within the context of watershed land use planning, public utility and service development policies and practices should discourage indiscriminant urban development on floodlands while encouraging essentially natural, open space uses. Although watershedwide floodland delineations are an invaluable aid in watershed management, precise floodland delineations were not, until the conduct of this study, available for the Menomonee River watershed. Floodland delineations constitute an important output of the Menomonee River watershed planning program.

Groundwater Resources: The Menomonee River watershed is richly endowed with groundwater resources. Groundwater is the source of water supply for many industries and for approximately 20 percent of the 348,000 people who reside in the watershed, and also supplies the baseflow to the Menomonee River and its tributaries. The amount of groundwater stored in the rocks directly beneath the Menomonee River valley is enormous, and is estimated to exceed 15 million acre-feet, a quantity sufficient to cover the entire watershed to a depth of 175 feet. Unlike the surface water system of the Menomonee River watershed, which is largely independent of the surface water systems of adjacent watersheds, groundwater located directly below the watershed is an integral part of the groundwater system that lies beneath southeastern Wisconsin. Therefore, proposed groundwater withdrawals within the Menomonee River watershed should be evaluated with regard to their impact on the regional groundwater system.

Rock units that yield water in usable amounts to pumped wells and in important amounts to lakes and streams are called aquifers. The aquifers beneath the watershed differ widely in water yield capabilities and extend to great depths, probably attaining a thickness in excess of 2,200 feet in the lower portion of the watershed. Three major aquifers exist in the Menomonee River watershed. These are, in order from land surface downward: 1) the sand and gravel deposits in the glacial drift: 2) the shallow dolomite strata in the underlying bedrock; and 3) the Cambrian and Ordovician strata, composed of sandstone, dolomite, siltstone, and shale. Because of their relative nearness to the land surface, the first two aquifers are sometimes called "shallow aquifers," and the latter the "deep aquifer." Wells tapping these aquifers are referred to as shallow or deep wells, respectively.

The occurrence, distribution, movement, use, and quality of these important groundwater resources and their interrelationship with surface water resources and other elements of the planning study are discussed in considerable detail in subsequent chapters of this report.

Fish and Wildlife Resources

Because of the large population of the Menomonee River watershed relative to its size, and because of its position within the larger metropolitan area, there is a high potential demand for fishing. Wildlife are desirable in urban and urbanizing areas primarily because of their aesthetic and educational values and the element of naturalness and diversity that they impart to the urban area.

Fishery: Wisconsin Department of Natural Resources, Bureau of Research personnel inventoried the fish population of the Menomonee River watershed stream system in late summer of 1973 in order to determine the current status of the watershed fishery. These field studies were also intended to provide a basis for analyzing the potential for further fishery development within the watershed stream system. Survey findings are summarized in this chapter and discussed in detail in Chapter IX of this volume.

The fishery inventory was accomplished with a fish shocking technique applied to 28 stations—each about 300 feet long—distributed throughout the watershed surface water system. Of the total of 28 stations, 25 were located on the stream system and three at ponds that were hydraulically connected to the stream system. All of the fish captured at each of these sampling stations were identified as to species and counted. Data collection included a length measurement for all game fish, panfish, and the larger nongame fish. A supplementary benthic sampling and analysis was conducted at six upper watershed stations. This involved taking bottom samples and sorting, identifying, and counting the benthic fauna found in the samples. Data from the supplementary benthic study, when combined with similar data from earlier benthic investigations, provided qualitative and quantitative information needed to interpret the existing fish community and to ascertain the potential for fishery development.

A total of 4,701 fish representing 23 different species were taken at the 28 stations during the field survey. Map 23 summarizes the findings of the watershed fishery inventory by showing the number of fish within each species taken at each of the 28 stations. Most of the fish found in the survey were pollution tolerant species having little or no recreational fishery value. In terms of frequency of occurrence in the watershed surface water system, the five most common species listed in order of decreasing abundance were central mudminnow, green sunfish, black bullhead, goldfish, and the brook stickleback.

Wildlife: Since the early settlement of the Menomonee River watershed by Europeans, there has been a sharp decrease in the variety and quantity of wildlife. This is a loss not only to hunters and other sportsmen, but to the health and diversity of the total environment. During 1973, Wisconsin Department of Natural Resources, Bureau of Research personnel conducted an inventory of the remaining wildlife and wildlife habitat in the watershed using aerial photo inspection followed by field surveys of many of the sites. In addition to providing a qualitative and quantitative description of the watershed's present wildlife resources, this inventory was intended to provide a basis for identifying those wildlife habitat areas that should, under the land use element of the Menomonee River watershed plan, be preserved and protected. The results of the wildlife habitat survey are summarized below, while a more detailed discussion is presented in Chapter IX of this volume.

A total of 100 wildlife habitat areas were identified and rated as shown on Map 24. Based on its current condition, each wildlife habitat area was categorized into one of the following four value rating categories:

1. High quality area—generally undisturbed and having a high plant and animal diversity. The Tamarack Swamp on the watershed divide in the Village of Menomonee Falls is an example of a high quality wildlife habitat area.

2. Good quality area—some disturbance but still retaining a good plant and animal diversity. Franklin Wirth Park in the City of Brookfield and the contiguous open lands to the northwest is an example of a good quality wildlife habitat area.

3. Moderate quality area—considerable disturbance and exhibiting low plant and animal diversity. The riverine area along most of the Little Menomonee River in Ozaukee and Milwaukee Counties is typical of a wildlife habitat area of moderate quality.

4. Low quality area—a remnant or markedly deteriorated former wildlife habitat area. Scattered small areas along the eastern edge of the Village of Menomonee Falls are typical of this type of wildlife habitat area.

Factors which must be considered in assigning value ratings to wildlife habitat areas are the size of the area; the presence of protective vegetation; and the proximity of streams, ponds, and other surface water areas. In addition to the value rating categorization, the wildlife habitats in the Menomonee River watershed were classified according to the wildlife type to which the habitats were suited. A classification was also provided to identify those wildlife areas most susceptible to further deterioration.

Map 24 indicates that most of the wildlife habitat areas remaining in the Menomonee River watershed are in the moderate quality category. A total of 22 good quality wildlife habitats remain in the watershed, located largely in the headwater areas. Only three high quality wildlife habitat areas still exist in the watershed—the Tamarack Swamp in the Village of Menomonee Falls, a small site known as Feld Maple Woods in the northwest corner of Menomonee Falls, and the large woodland-wetland area known as the Germantown Swamp in the northeast corner of the Village of Germantown.

Park, Outdoor Recreation, and Related Open Space Sites

Existing Sites: An inventory of the existing parks, outdoor recreation areas, and related open space sites was conducted within the Region and the watershed during 1974, under the regional park, outdoor recreation, and related open space planning program of the Commission. This inventory revealed that there are a total of 243 existing park, outdoor recreation, and related open space sites within the watershed, totaling 6,138 acres, or about 7 percent of the watershed area. The distribution of these sites by ownership is shown in Table 18, and by ownership and county in Table 19. The spatial distribution of existing parks, outdoor recreation areas, and related open spaces is shown on Map 25, while Figure 15 illustrates the relative size of such areas to the watershed as a whole and also facilitates a comparison of public and private holdings. Of the total 243 sites and 6,138 acres of existing park, outdoor recreation, and related open space in the watershed, public ownership accounts for 177 sites covering 5,460 acres, or 89 percent of the total acreage, while nonpublic ownership accounts for the remaining 66 sites encompassing 678 acres, or 11 percent of the total acreage.

Of the 5,460 acres of park, outdoor recreation, and related open space sites in public ownership, about 77 percent is owned by Milwaukee County, and most of that consists of parkway lands along the Menomonee and Little Menomonee Rivers and Underwood and Honey Creeks. Other government acreage, while small in comparison to the Milwaukee County total, consists mainly of intensively used park and active outdoor recreation areas within the urban centers of the watershed.

Table 18

EXISTING PARK, OUTDOOR RECREATION, AND RELATED OPEN SPACE SITES IN THE MENOMONEE RIVER WATERSHED BY OWNERSHIP: 1974

Ownership	Sites Number	Sites Acres	Percent of Total Public Sites	Percent of Total Acreage in Public Sites	Percent of Total Nonpublic Sites	Percent of Total Acreage in Nonpublic Sites	Percent of Total Sites	Percent of Total Acreage
Public								
State	1	180	0.6	3.0	--	--	0.4	3.0
County	38	3,538	21.4	65.0	--	--	15.6	58.0
City or Village	51	976	29.0	18.0	--	--	21.0	16.0
School District or System	87	766	49.0	14.0	--	--	36.0	12.0
Subtotal	177	5,460	100.0	100.0	--	--	73.0	89.0
Nonpublic								
Organizational	47	274	--	--	71.0	40.0	19.0	4.0
Commercial	10	102	--	--	15.0	15.0	4.0	2.0
Private (restricted)	9	302	--	--	14.0	45.0	4.0	5.0
Subtotal	66	678	--	--	100.0	100.0	27.0	11.0
Total	243	6,138	--	--	--	--	100.0	100.0

Source: SEWRPC.

Table 19

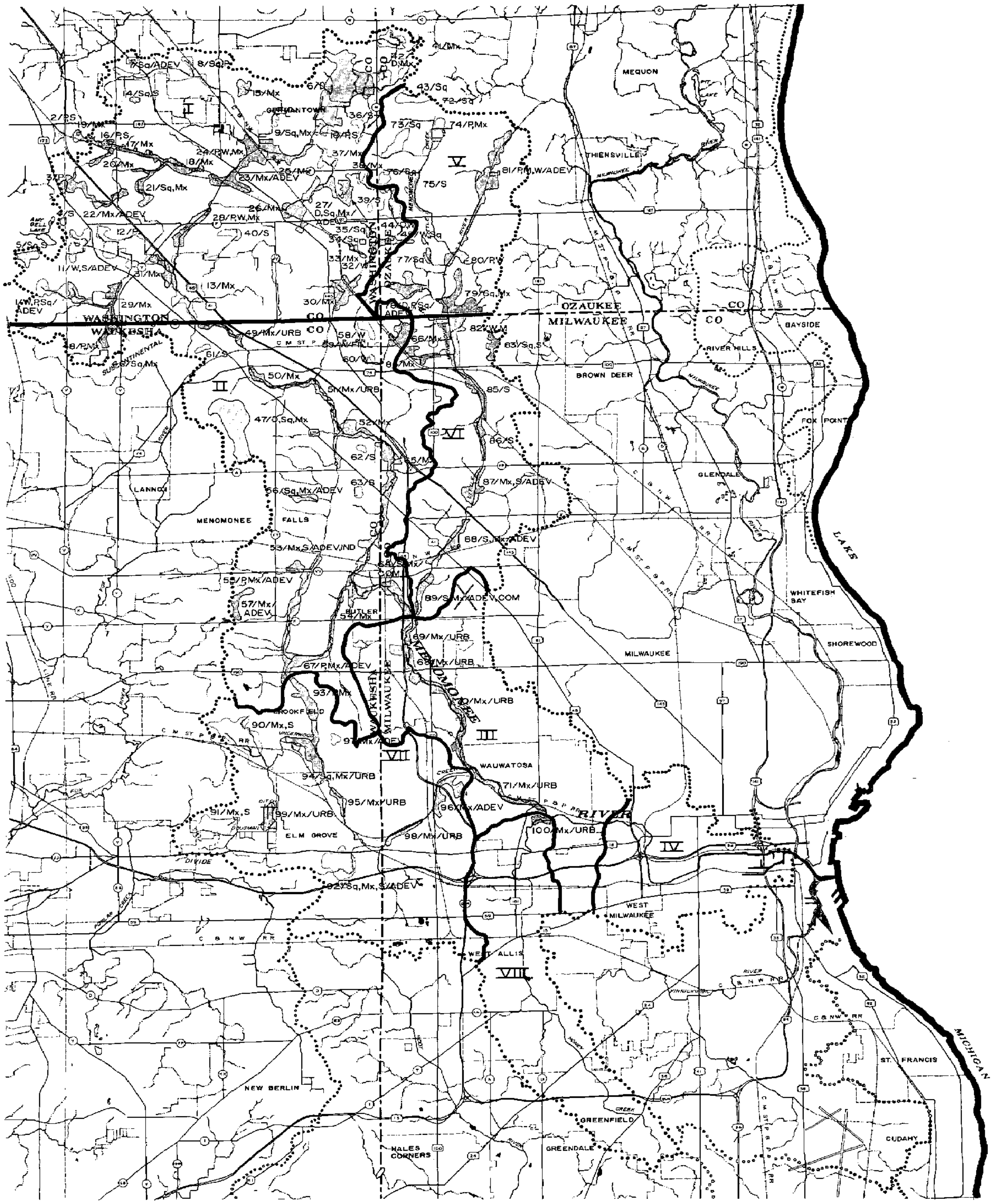
EXISTING PARK, OUTDOOR RECREATION, AND RELATED OPEN SPACE SITES IN THE MENOMONEE RIVER WATERSHED BY OWNERSHIP AND COUNTY: 1974

Ownership	County: Milwaukee Sites	Milwaukee Acres	Ozaukee Sites	Ozaukee Acres	Washington Sites	Washington Acres	Waukesha Sites	Waukesha Acres	Total Sites	Total Acres
Public										
State	1	180	0	0	0	0	0	0	1	180
County	38	3,538	0	0	0	0	0	0	38	3,538
City or Village	23	173	0	0	4	148	24	655	51	976
School District or System	58	308	0	0	8	121	21	337	87	766
Subtotal	120	4,199	0	0	12	269	45	992	177	5,460
Nonpublic										
Organizational	32	226	1	6	3	15	11	27	47	274
Commercial	5	58	0	0	2	3	3	41	10	102
Private (restricted)	4	52	0	0	1	210	4	40	9	302
Subtotal	41	336	1	6	6	228	18	108	66	678
Total	161	4,535	1	6	18	497	63	1,100	243	6,138

Source: SEWRPC.

Map 24

WILDLIFE HABITAT AREAS IN THE MENOMONEE RIVER WATERSHED: 1973



LEGEND

I	IDENTIFICATION OF ECOLOGICAL UNIT
3	SITE NUMBER

VALUE RATING:

- HIGH QUALITY AREA—GENERALLY UNDISTURBED, A HIGH PLANT AND ANIMAL DIVERSITY
- GOOD QUALITY AREA—SOME DISTURBANCE, A GOOD PLANT AND ANIMAL DIVERSITY
- MODERATE QUALITY AREA—CONSIDERABLE DISTURBANCE, A LOW PLANT AND ANIMAL DIVERSITY
- LOW QUALITY AREA—A REMNANT OR DETERIORATED HABITAT

WILDLIFE TYPES:

W	WATERFOWL
M	MUSKRAT
P	PHEASANT
D	DEER
Sq	SQUIRREL
S	SONGBIRDS
Mx	MIXED

THREAT CLASSIFICATIONS:

ADEV	ADVANCING DEVELOPMENT
URB	URBAN ACTIVITY IN CLOSE PROXIMITY
COM	COMMERCIAL ACTIVITY IN CLOSE PROXIMITY
IND	INDUSTRIAL ACTIVITY IN CLOSE PROXIMITY
FILL	FILLING OCCURRING

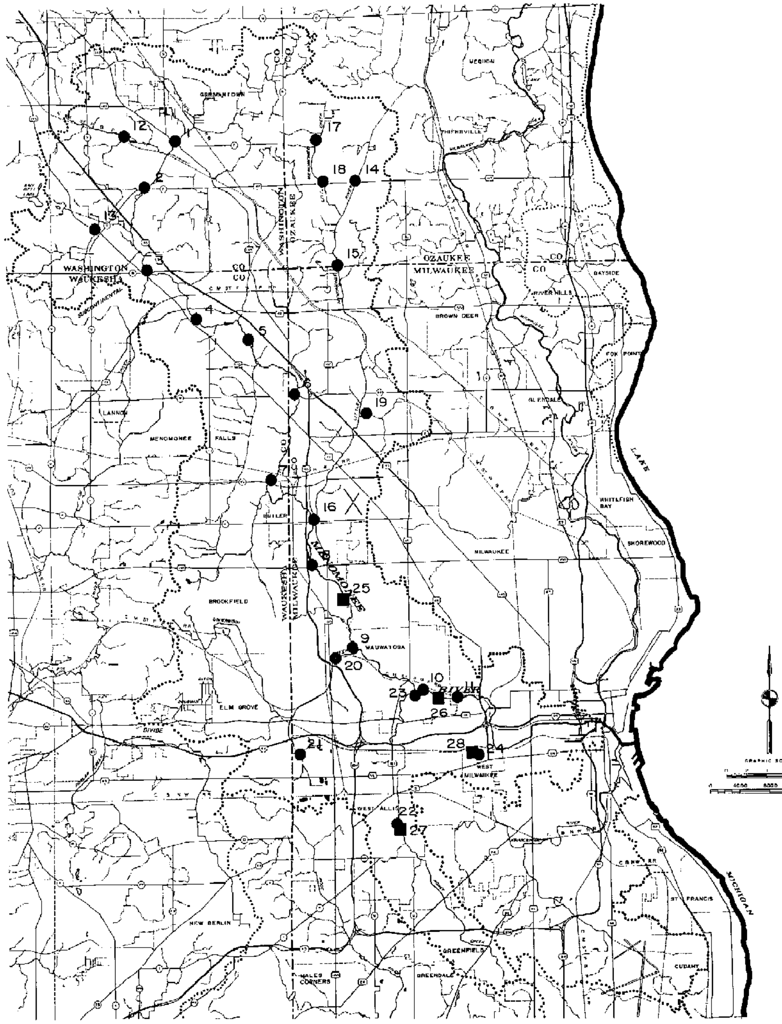
GRAPHIC SCALE
0 1/2 1 2 3 MILES
0 4000 8000 12000 16000 20000 FEET

An inventory of wildlife habitat revealed that, as of 1973, a total of 100 significant habitat areas remained in the Menomonee River watershed. As shown on this map, the few remaining good quality and high quality wildlife habitat areas are concentrated in the predominantly rural headwater areas of the basin, an area that is currently being subjected to scattered urbanization pressures. Unless consciously protected, these remaining good quality and high quality wildlife habitat areas will diminish both in quality and quantity. A sound watershed plan should recommend the protection and preservation of selected wildlife habitat areas because of their ecological significance for watershed flora and fauna, and their aesthetic and recreational value to the human population.

Source: SEWRPC.

Map 23

FISHERY RESOURCES IN THE MENOMONEE RIVER WATERSHED: AUGUST-SEPTEMBER 1973



LEGEND

- ● STREAM FISH SHOCKING STATION
- ■ POND FISH SHOCKING STATION
- 1 STATION NUMBER

FISH SPECIES AND THEIR IDENTIFICATION NUMBERS LISTED IN ORDER OF DECREASING TOLERANCE TO POLUTION

VERY TOLERANT

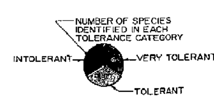
1 CENTRAL MUDMINNOW	2 GOLDFISH
3 CARP	4 BLACK BULLHEAD
5 WHITE SUCKER	6 FATHEAD MINNOW

TOLERANT

7 BLUNT NOSE MINNOW	8 GREEN SUNFISH
9 PUMPKINSEED	10 CREEK CHUB
11 BLUEGILL	12 LARGEMOUTH BASS
13 YELLOW PERCH	14 BROOK STICKLEBACK
15 GOLDEN SHINER	16 COMMON SHINER

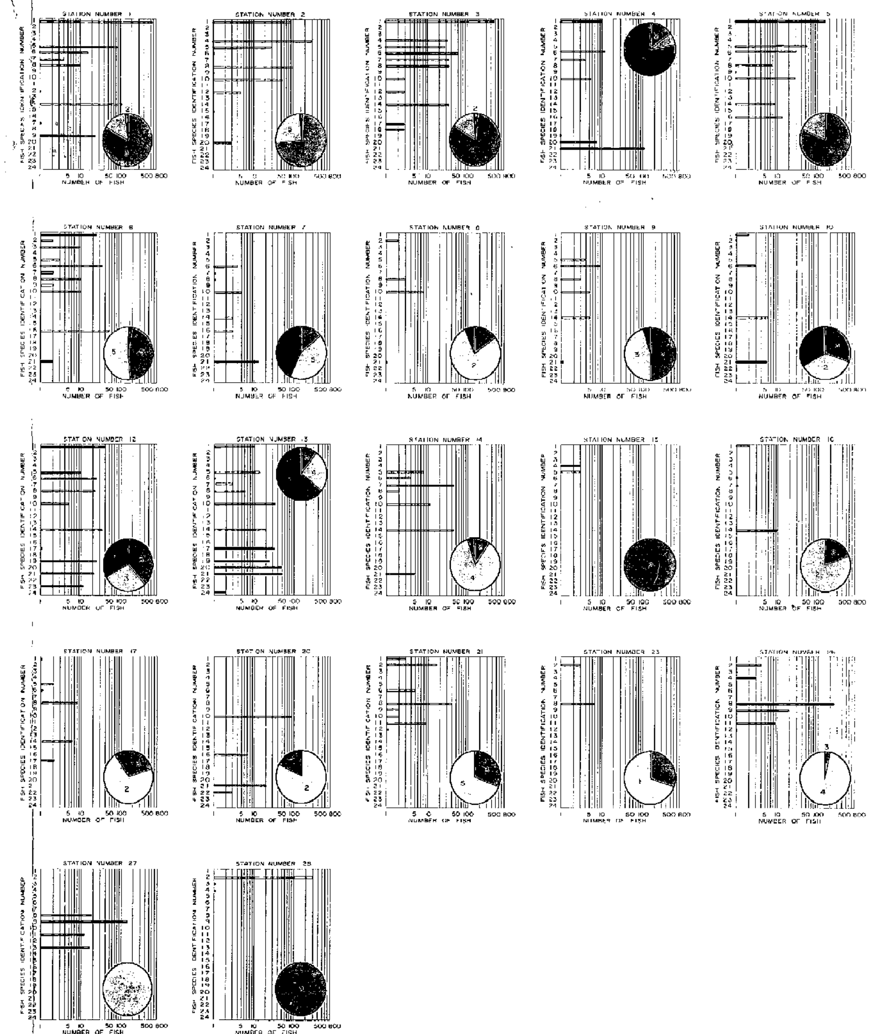
INTOLERANT

17 JOHNNY DARTER	18 BRASSY MINNOW
19 PEARL DACE	20 STONE ROLLER
21 BLACK-NOSED DACE	22 SOUTHERN RED BELLY DACE
23 NORTHERN RED BELLY DACE	24 FANTAIL DARTER



NOTE: EACH CIRCLE REPRESENTS THE TOTAL NUMBER OF FISH COLLECTED AT EACH SHOCKING SITE

NOTE: SUMMARY GRAPHS ARE OMITTED FOR THOSE 6 SHOCKING STATIONS AT WHICH ONE OR NO FISH WERE OBTAINED IN ALL SPECIES

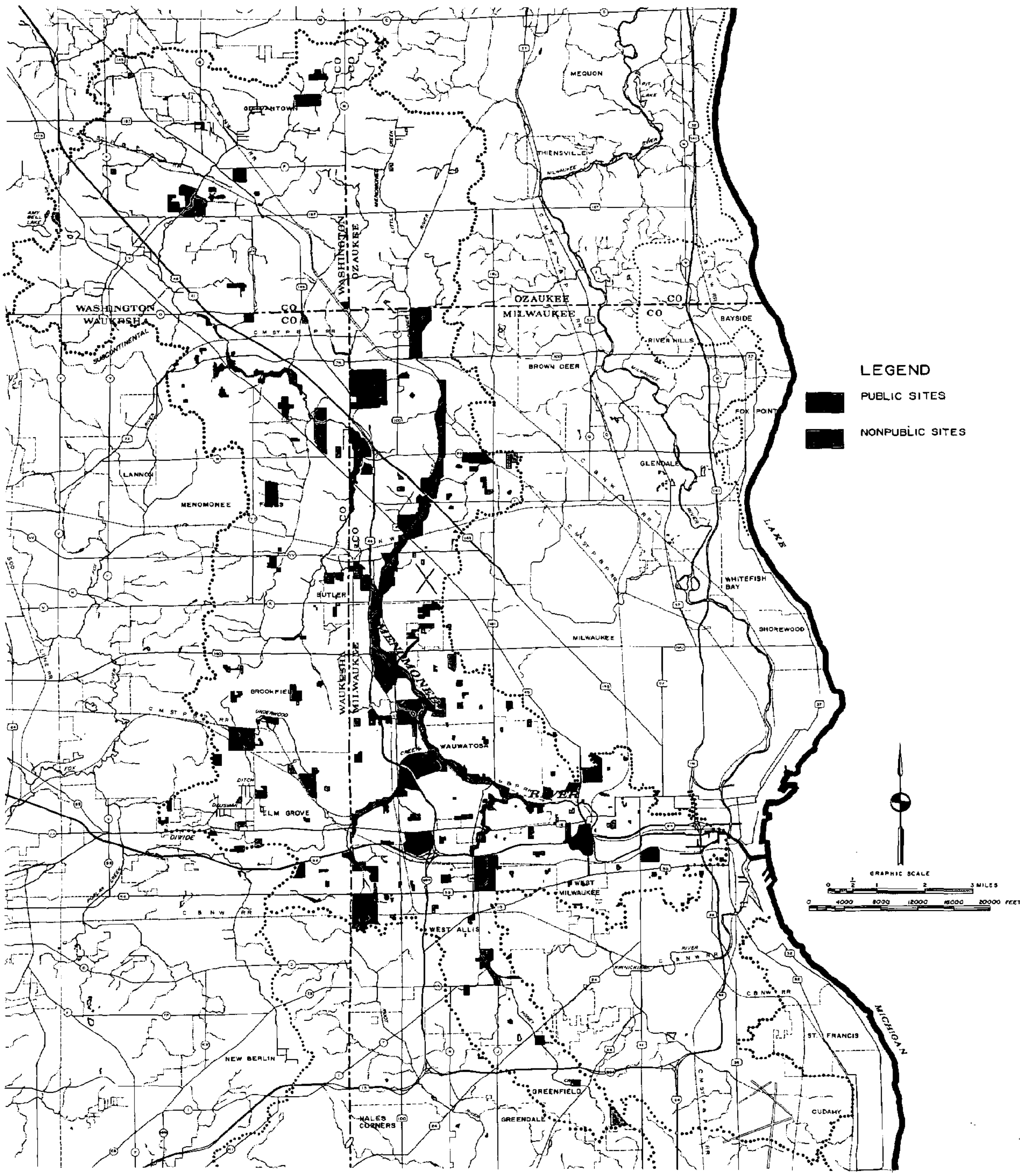


This map summarizes the results of a fishery inventory conducted throughout the watershed in late summer of 1973. A fish shocking technique was used at 28 locations in the watershed surface water system, and 23 different fish species were identified. Most of the fish taken in the survey were pollution tolerant species having little or no recreational fishery value. The dominance of pollution tolerant fish relative to the more desirable pollution intolerant fish is an indication of the degraded quality of the watershed's surface water system.

Source: SEWPRC.

Map 25

EXISTING PARK, OUTDOOR RECREATION, AND RELATED OPEN SPACE SITES
IN THE MENOMONEE RIVER WATERSHED: 1974

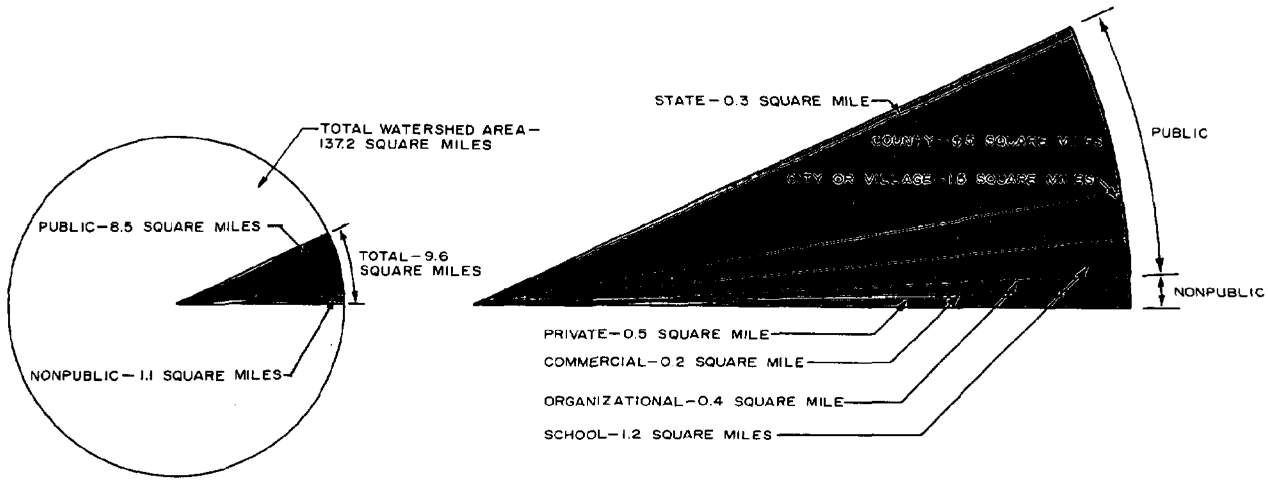


A total of 243 park, outdoor recreation, and related open space sites encompassing 6,138 acres exist in the Menomonee River watershed. About 89 percent of this land is owned by public entities such as the state, counties, cities and villages, and school systems. The remainder of the park, outdoor recreation, and related open space sites are owned by nonpublic entities such as parochial schools and private golf clubs. About 77 percent of the publicly owned land is in Milwaukee County, where it consists primarily of linear, continuous riverine area parklands.

Source: SEWRPC.

Figure 15

AREAL EXTENT OF EXISTING PARK, OUTDOOR RECREATION, AND RELATED OPEN SPACE SITES IN THE MENOMONEE RIVER WATERSHED BY OWNERSHIP: 1974



Source: SEWRPC.

The nonpublic recreation sites, consisting of private, organizational, and commercially operated recreation lands, account for about 27 percent of the number of sites in the watershed but for only 11 percent of the acreage. Over 40 percent of the nonpublic acreage, or 274 acres, is owned by organizations such as parochial schools. About 102 acres are operated on a profit-making commercial basis.

Potential Sites: An inventory of potential outdoor recreation and related open space sites was also conducted within the Region during 1974 under the Commission's regional park, outdoor recreation, and related open space planning program. The results of these inventories within the Menomonee River watershed are shown on Map 26 and summarized in Tables 20 and 21.

Each potential outdoor recreation and related open space site was evaluated and assigned a high, medium, or low value rating. These ratings were based on a variety of factors such as existing land use at and near the site; site size; the presence of significant natural attractions such as a lake, a river, woodlands, or rock outcrops; historic or archeological significance; accessibility; and overall development possibilities. The potential sites were also categorized according to size by means of size ranges, which in the Menomonee River watershed included the following three ranges: 0-150 acres, 150-300 acres, 300-500 acres, and more than 1,000 acres.

A total of 18 potential recreation and related open space sites were identified in the watershed—one in Milwaukee County, three in Ozaukee County, five in Washington County, and nine in Waukesha County. Fourteen of the eighteen sites are in the smaller size category—less than 150 acres. Only one site—the Tamarack Swamp in the Village of Menomonee Falls—is in the largest size category—greater than 1,000 acres. The dominance of small potential sites reflects the urban and urbanizing characteristics of the Menomonee River watershed.

Environmental Corridors

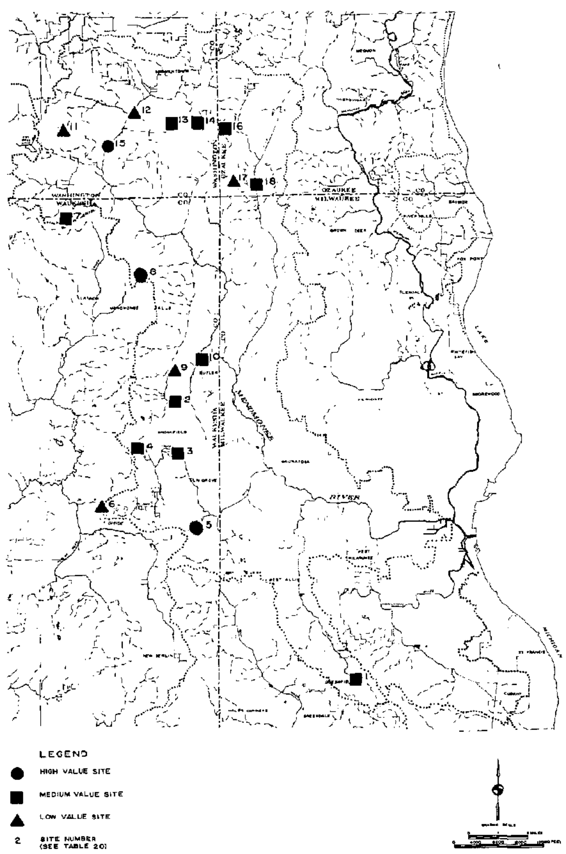
The Corridor Concept: One of the most important tasks which was completed as part of the regional land use planning effort was the identification and delineation of those areas of the Region in which concentrations of recreational, aesthetic, ecological, and cultural resources occur and which, therefore, should be preserved and protected. Such areas normally include one or more of the following seven elements of the natural resource base which are essential to the maintenance of both the ecological balance and natural beauty of the Region.

1. Lakes, rivers, and streams and their associated floodlands.
2. Wetlands.
3. Woodlands.
4. Wildlife habitat areas.
5. Rugged terrain and high-relief topography.
6. Significant geological formations and physiographic features.
7. Wet or poorly drained soils.

Although the foregoing elements comprise the integral parts of the natural resource base, there are four additional elements which, although not a part of the natural

Map 26

POTENTIAL RECREATION AND RELATED OPEN SPACE SITES IN THE MENOMONEE RIVER WATERSHED: 1974



Inventories conducted under the Commission's regional park, outdoor recreation, and related open space planning program revealed that a total of 18 potential recreation and related open space sites with a combined area of about 4,000 acres remain in the Menomonee River watershed. Over two-thirds of these sites were in the smallest size category—less than 150 acres—and only three sites were assigned high value ratings.

Source: SEWRPC.

resource base per se, are closely related to or centered on that base and are a determining factor in identifying and delineating areas with scenic, recreational, and historic value. These additional elements are:

1. Existing outdoor recreation sites.

2. Potential outdoor recreation and related open space sites.

3. Historic sites and structures.

4. Significant scenic areas and vistas.

The delineation of these natural resource and natural resource related elements on a map of the Region results in an essentially lineal pattern encompassed in narrow, elongated areas which have been termed "environmental corridors" by the Commission. Primary environmental corridors are defined as those areas which generally encompass three or more of the aforementioned 11 environmental elements, whereas secondary environmental corridors are contiguous areas exhibiting one or two of the 11 necessary elements.

Watershed Environmental Corridors: The primary and secondary environmental corridors existing in the Menomonee River watershed as delineated by the Commission in 1964 during preparation of the land use plan for the Region are shown on Map 27. The primary environmental corridors of the watershed, most of which lie along stream valleys, were found to occupy approximately 18 gross square miles or about 13 percent of the total area of the watershed. The gross primary environmental corridor area is defined as including all land uses, both urban and rural, whereas, the net primary environmental corridor area is defined as the gross corridor acreage minus the noncompatible urban land use acreages in the corridor. Net corridor areas consist of recreational land use, agricultural and related land uses, water, wetlands and woodlands uses, and other open space land uses. Net primary corridor areas in the watershed total nearly 15 square miles or nearly 11 percent of the watershed area.

It is important to note that the primary environmental corridors contain almost all of the remaining high value wildlife habitat areas and woodlands within the watershed, in addition to most of the wetlands, streams, and associated floodlands. These corridors also contain many of the best remaining potential park sites. The primary environmental corridors are, in effect, a composite of the best of the individual elements of the natural resource base of the Menomonee River watershed, which elements have been separately discussed in this chapter.

Recent trends within southeastern Wisconsin in general, and the Menomonee River watershed in particular, have resulted in the encroachment of urban development into the primary environmental corridors as they were originally delineated in 1963. Unfortunately, unplanned or poorly planned intrusion of urban development into these corridors not only tends to destroy the very resources and related amenities sought by the development, but tends to create severe environmental problems having areawide effects.

Both the primary and secondary environmental corridor delineations were refined under the Menomonee River watershed planning program as described in Chapter III, Volume 2, of this report. This refinement was necessitated partly by the aforementioned encroachment of urban development into the original environmental corridors, and partly by the availability of additional or more refined data pertaining to the seven elements of the natural resources base and the four natural resource related elements used to delineate the corridors. Examples

Table 20

LOCATION OF POTENTIAL RECREATION AND RELATED OPEN SPACE SITES IN THE MENOMONEE RIVER WATERSHED: 1974

Site Number[a]	Location						Acreage Range[b]				Site Value Rating		
	U. S. Public Land Survey				Civil Division								
	Township (North)	Range (East)	Section	Quarter Section	County	City, Village, or Town	Less Than 150	150 to 300	300 to 500	More Than 1,000	High	Medium	Low
1	06	22	26	NW	Milwaukee	City of Greenfield	X	--	--	--	--	X	--
2	07	20	02	SW	Waukesha	City of Brookfield	X	--	--	--	--	X	--
3	07	20	14	NW	Waukesha	City of Brookfield	X	--	--	--	--	X	--
4	07	20	15	NW	Waukesha	City of Brookfield	X	--	--	--	--	X	--
5	07	20	25	SW	Waukesha	City of Brookfield	--	X	--	--	X	--	--
6	07	20	29	NE	Waukesha	Town of Brookfield	--	--	X	--	--	--	X
7	08	20	06	SE	Waukesha	Village of Menomonee Falls	X	--	--	--	--	X	--
8	08	20	15	NW	Waukesha	Village of Menomonee Falls	--	--	--	X	X	--	--
9	08	20	35	SW	Waukesha	Village of Menomonee Falls	X	--	--	--	--	--	X
10	08	20	36	NE	Waukesha	Village of Butler	--	X	--	--	--	X	--
11	09	20	19	SW	Washington	Village of Germantown	X	--	--	--	--	--	X
12	09	20	22	NW	Washington	Village of Germantown	X	--	--	--	--	--	X
13	09	20	23	NE	Washington	Village of Germantown	X	--	--	--	--	X	--
14	09	20	24	NW	Washington	Village of Germantown	X	--	--	--	--	X	--
15	09	20	28	NW	Washington	Village of Germantown	X	--	--	--	X	--	--
16	09	21	19	SW	Ozaukee	City of Mequon	X	--	--	--	--	X	--
17	09	21	31	NW	Ozaukee	City of Mequon	X	--	--	--	--	--	X
18	09	21	32	NW	Ozaukee	City of Mequon	X	--	--	--	--	X	--

[a] See Map 26.

[b] The regional inventory of potential outdoor recreation and related open space sites included the following acreage ranges: less than 150, 150-300, 300-500, 500-750, 750-1,000, and more than 1,000. Within the Menomonee River watershed, the potential recreation and related open space sites include only four of the aforementioned acreage ranges: less than 150, 150-300, 300-500, and more than 1,000.

Source: SEWRPC.

Table 21

SIZE AND VALUE RATING OF POTENTIAL RECREATION AND RELATED OPEN SPACE SITES IN THE MENOMONEE RIVER WATERSHED BY COUNTY: 1974

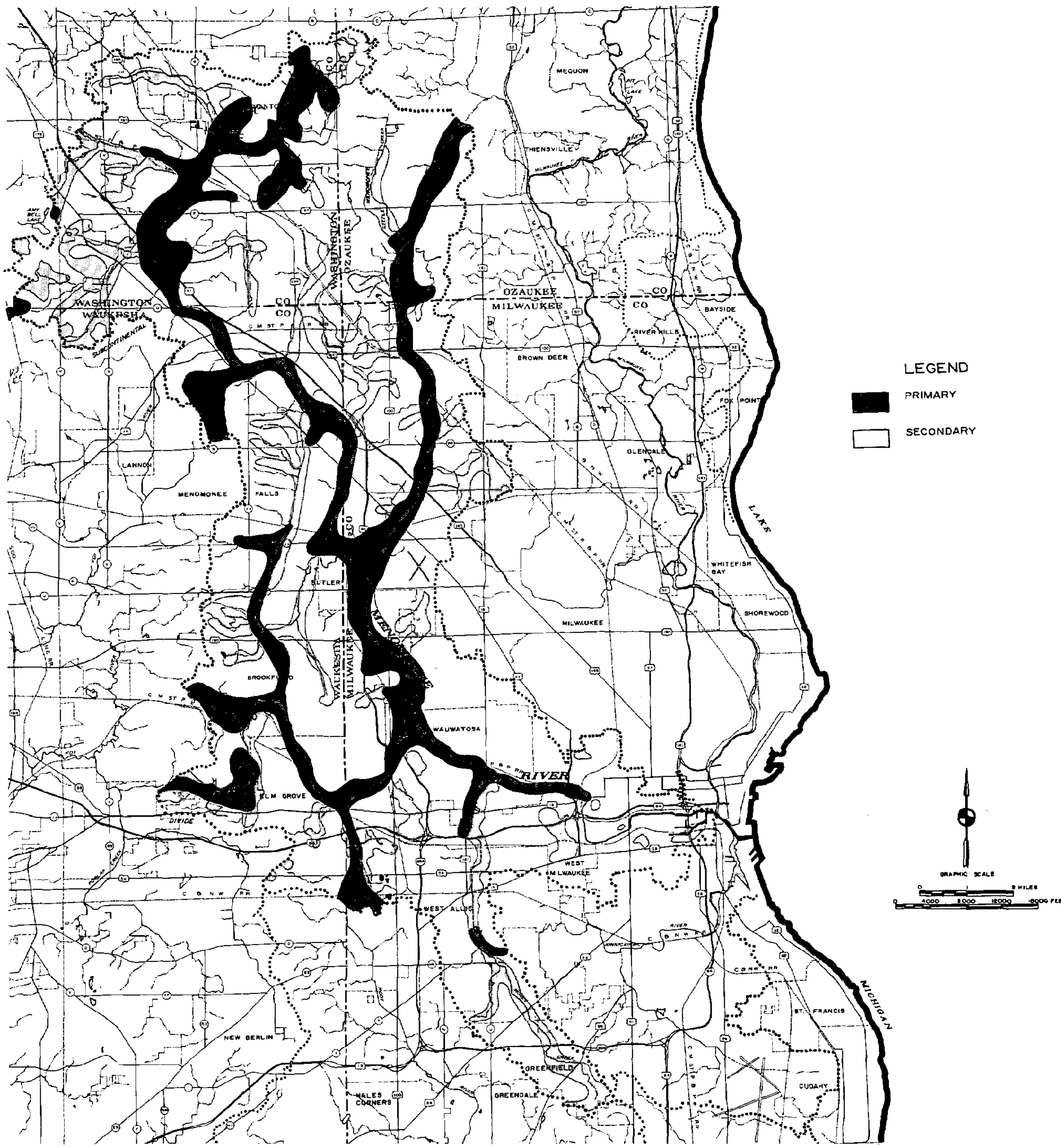
County	Acreage Range[a]												Total High Value Sites	Total Medium Value Sites	Total Low Value Sites	Total Sites
	0-150			150-300			300-500			More than 1,000						
	High Value	Medium Value	Low Value	High Value	Medium Value	Low Value	High Value	Medium Value	Low Value	High Value	Medium Value	Low Value				
Milwaukee . . .	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Ozaukee. . . .	0	2	1	0	0	0	0	0	0	0	0	0	0	2	1	3
Washington. . .	1	2	2	0	0	0	0	0	0	0	0	0	1	2	2	5
Waukesha . . .	0	4	1	1	1	0	0	0	1	1	0	0	2	5	2	9
Total	1	9	4	1	1	0	0	0	1	1	0	0	3	10	5	18

[a] The regional inventory of potential recreation and related open space sites included the following acreage ranges: less than 150, 150-300, 300-500, 500-750, 750-1,000, and more than 1,000. Within the Menomonee River watershed, the potential recreation and related open space sites include only four of the aforementioned acreage ranges: less than 150, 150-300, 300-500, and more than 1,000.

Source: SEWRPC.

Map 27

ENVIRONMENTAL CORRIDORS IN THE MENOMONEE RIVER WATERSHED: 1964



Primary environmental corridors encompass by definition almost all of the best woodlands, wetlands, and wildlife habitat areas; almost all the streams and associated undeveloped floodlands and shorelands; as well as many of the significant topographic, geologic, and historic features of the watershed. The best remaining ecological, aesthetic, and recreational resources of the Menomonee River watershed are thus concentrated in the primary environmental corridors. The preservation of these corridors in compatible open space uses is essential to maintaining the quality of the environment in the watershed.

Source: SEWRPC.

of additional or improved data obtained under the watershed planning program and therefore available for corridor refinement include floodland delineations and new wetland, woodland, and wildlife habitat determinations and ratings.

The preservation of the primary environmental corridors from further degradation is one of the principal objectives of the adopted regional land use plan upon which the Menomonee River watershed plan is based. They should be considered inviolate, and their preservation in a natural state or in park and related open space uses, including limited agricultural and country estate type uses, will serve to maintain a high level of environmental quality in the watershed and protect what remains of its natural beauty. Secondary environmental corridors should be at least partially retained in open space by using them as the basis for, or by integrating them into, greenways, drainageways, storm water detention basins, parks, and open spaces in developing areas of the Region.

SUMMARY

The Menomonee River watershed is a complex of natural and man-made features that interact to comprise a changing environment for human life. Future changes in the watershed ecosystem and the favorable or unfavorable impact of those changes on the quality of life within the watershed will be largely determined by man's actions. The Menomonee River watershed comprehensive planning program seeks to rationally direct those actions so as to favorably affect the overall quality of life in the watershed. This chapter describes the existing ecosystem of the watershed—the natural resource base and man-made features—thereby establishing a factual base upon which the watershed planning process may be built.

The man-made features of the watershed include its political boundaries, its land use pattern, its public utility network, and its transportation system. These features along with the resident population and the economic activities within the watershed may be thought of as the socioeconomic base of the watershed.

The 137 square mile Menomonee River watershed comprises 5 percent of the Southeastern Wisconsin Planning Region and is the fifth largest of the 11 distinct watersheds located wholly or partly within the Region. As it flows from its headwater areas in the southeastern corner of Washington County to its confluence with the Milwaukee River near the Lake Michigan shoreline, the Menomonee River passes through a wide spectrum of land uses ranging from essentially natural woodland-wetland areas to a highly developed residential, commercial, and industrial complex. Portions of four of the seven counties comprising the Southeastern Wisconsin Planning Region—Milwaukee, Waukesha, Washington, and Ozaukee—are contained within the Menomonee River watershed. Although the watershed is small, it encompasses parts or all of seven cities, six villages, and four towns.

The Metropolitan Sewerage District of the County of Milwaukee exists within the watershed as a special-purpose, areawide unit of government having important responsibilities for provision of sanitary sewerage service and sewage treatment and for water pollution control, and having authorization to provide flood control. The District plus its legally established contract sanitary sewer service area in Waukesha, Washington, and Ozaukee Counties encompasses 97 percent of the watershed area, thereby providing a mechanism for resolving not only areawide surface water pollution problems, but also drainage and flood control problems in the lower reaches of the watershed. Two sanitary districts encompassing the Village of Elm Grove are contained within the watershed, as is a very small part of one active local drainage district and four soil and water conservation districts corresponding to each of the four counties.

The 1970 population of the watershed was estimated at 348,165 persons, or 20 percent of the total population of the Region. Since 1900, Menomonee River watershed population growth rates have generally exceeded those of the Region, the state, and the nation. The greatest proportion of the watershed population—80 percent—resides in Milwaukee County, which comprises 41 percent of the watershed's area. The proportion of the watershed population residing in Milwaukee County has decreased in the last two decades, from 94 percent in 1950, as the population shifted into the Waukesha, Washington, and Ozaukee County portions of the watershed. Population densities range from less than 350 persons per gross square mile in headwater areas to over 25,000 persons per gross square mile in the highly urbanized lower portions of the watershed. Age, household size, and household income data indicate that the recent and current urbanization of the middle and upper portions of the watershed involves younger, larger family units with above average incomes.

Rapid urbanization of the Menomonee River watershed may be attributed, in part, to increasing economic activity within the watershed and surrounding four county metropolitan area. Of eight major industrial groups, 35 percent of the employment in that four county area is in the manufacturing sector. Watershed industrial activity is concentrated in the City of Milwaukee, where 44 of the 69 industrial firms in the watershed employing 150 or more persons are located.

Most of the watershed's remaining agricultural economic activity is located in the Washington and Ozaukee County portions of the watershed. A 6.9 square mile, or 13 percent, reduction in watershed land devoted to agricultural and related land uses occurred from 1963 to 1970. This reduction in agricultural land use coupled with other signs of urbanization suggests an impending reduction in the role of agriculture in the economy of the Menomonee River watershed.

The settlement of the watershed followed establishment of the port city of Milwaukee, with the pattern of historic urbanization generally occurring in expanding, concentric rings around the port area. Urbanization proceeded very rapidly during the 1950 to 1970 period, as evidenced by a 42 percent increase in watershed population and a 156 percent increase in land devoted to urban uses.

As of 1970, 73 square miles, or 53 percent of the watershed area, were in urban as opposed to rural land use. The dominant urban land use in the watershed is residential, which encompasses 34 square miles, or 25 percent of the watershed area. The larger, contiguous remaining rural lands are located in the Washington and Ozaukee County portions of the watershed.

The watershed's public utility base is composed of its sanitary sewerage systems, water supply systems, electric power service, and gas service. Adequate supplies of both electric power and natural gas are available, or could be readily provided, to all areas of the watershed. Although the historical liberal electric and gas utility service policies have not as yet been changed, there is some indication that the privately owned utilities may move toward more restrictive policies in the near future. Expansion of sanitary sewerage and water supply systems has not fully kept pace with the rapid urbanization of the Menomonee River watershed. As a result, there are significant concentrations of unsewered urban development in the watershed, primarily in the City of Brookfield and the Village of Menomonee Falls. About 61 square miles, or 84 percent of the urbanized area of the watershed and 45 percent of the total watershed area, and approximately 311,500 people, or about 89 percent of the total watershed population, were served by public sanitary sewerage facilities in 1970. The largest concentrations of watershed urban development not served by public water supply systems are located in the City of Brookfield and the Villages of Elm Grove and Menomonee Falls. In 1970, approximately 56 square miles, or 77 percent of the urbanized area of the watershed, 41 percent of the total watershed area, and 85 percent of the total watershed population, were served by public water supply systems. The four public water utilities located in the Milwaukee County portion of the watershed utilize Lake Michigan as a source, whereas all of the four public utilities in the Waukesha and Washington County parts of the watershed draw on the groundwater reservoir.

The watershed is well served by an extensive all-weather high-speed highway system which includes 35.4 miles of freeway. Partly because of that highway system, strong urbanization pressures may be expected to be exerted on the remaining rural headwater areas of the watershed, since they are located within a 30-minute driving time of lower watershed centers of employment, shopping, and service. Three types of bus service are available in the watershed: urban mass transit, intercity bus service, and suburban mass transit. Urban mass transit service is provided to much of the intensely urbanized portion of the watershed within Milwaukee County.

Railroad service in the watershed is limited to freight hauling, except for scheduled Amtrak passenger service over the lines of the Chicago, Milwaukee, St. Paul and Pacific Railroad Company (Milwaukee Road) between the Union Station in Milwaukee, which is the only stop in the watershed, and Chicago to the south and Minneapolis-St. Paul to the west. Two of the largest Milwaukee metropolitan area railroad classification yards are located within the Menomonee River watershed—the Milwaukee Road's industrial valley yard and the "Butler" yard of the Chicago & Northwestern Railroad. Both of the railroads serving the watershed traverse the remaining rural headwater areas of the watershed, and the resulting potential to provide freight service to these areas and thereby support new commercial and industrial activity may contribute to urbanization pressures in the watershed headwaters. An active commercial shipping operation, handling bulk materials such as coal, sand, stone, cement, and scrap metals, exists along the 1.7 mile Menomonee River reach downstream of 25th Street extended in the City of Milwaukee.

The natural resource base of the watershed is a composite of climate, physiography, geology, mineral resources, soils, vegetation, water resources, and fish and wildlife resources. Inasmuch as the underlying and sustaining natural resource base is highly vulnerable to misuse and destruction, the management of that resource base must be a primary consideration in the Menomonee River watershed planning effort.

Because of its mid-continental location, far removed from the moderating effect of the oceans, the Menomonee River watershed has a climate characterized by a progression of markedly different seasons. An essentially continuous pattern of distinct weather changes occurring at two to three day intervals is superimposed on the seasonal pattern. Air temperatures in the watershed range from a daily average of about 20°F in January to 72°F in July. Watershed temperature extremes have ranged from a low of about -30°F to a high of approximately 108°F.

Average annual precipitation within the watershed is 29.1 inches expressed as water equivalent, and average monthly amounts range from a low of 0.97 inch in February to 3.61 inches in July. The average annual amount of snow and sleet expressed as snow and sleet is 42.0 inches which, when converted to its water equivalent, constitutes 15 percent of the total annual precipitation. About 94 percent of the annual snowfall occurs in the four months of December, January, February, and March. Annual total precipitation in the vicinity of the watershed has varied from a low of 17 inches to a high of 50 inches. Snowfall has, relative to the annual average, historically exhibited a wider variation than total precipitation, with the annual snowfall ranging from a low of five inches to a high of approximately 109 inches.

With respect to snow cover, there is a 0.25 probability of having five or more inches of snow on the ground during January and the first half of February. A minimum of six or more inches of frozen ground normally exists in the watershed during January, February, and the first half of March. Annual potential evaporation in the watershed is about 29 inches and is approximately equal, both annually and seasonally, to precipitation. Prevailing winds follow a clockwise pattern in terms of prevailing direction over the seasons of the year, being northwesterly in the late fall and winter, northeasterly in the spring, and southwesterly in the summer and early fall.

Daylight in the watershed ranges from a minimum of 9.0 hours on about December 22nd to a maximum of 15.4 hours on about June 21st. The smallest amount of daytime sky cover occurs from July through October, when the mean monthly daytime sky cover is approximately 0.5, whereas a sky cover of about 0.7 may be expected from November through March.

Watershed topography and physiographic features have been largely determined by the underlying bedrock and overlying glacial deposits. The last of the four major stages of glaciation occurred about 11,000 years ago, and was the most influential in sculpturing the watershed land surface. The Niagara cuesta on which the watershed lies is a gently eastward sloping bedrock surface. The topography in this section is asymmetrical, with the eastern border of the watershed being generally lower—about 150 to 300 feet—than the western border.

The northwest portion of the watershed lies closest to the Kettle Moraine, and contains rolling ground moraine similar to, but more subdued than, the kettle and kame topography of the Kettle Moraine. Surface elevations within the watershed range from a high of approximately 1,120 feet above sea level in the northwest area of the watershed to a low of approximately 580 feet above sea level in the Menomonee River industrial valley, a maximum relief of 540 feet.

A major subcontinental divide separating Mississippi River basin drainage from Great Lakes-St. Lawrence River basin drainage forms much of the western boundary of the Menomonee River watershed, the stream system of which discharges to Lake Michigan. Surface drainage within the watershed is very diverse with respect to channel shape and slope, the degree of stream sinuosity, and floodland shape and width. The heterogeneous character of the surface drainage system is partly due to the natural effect of glacial drift and partly attributable to the extensive channel modifications evident in the lower watershed.

The geology of the Menomonee River watershed is a complex system of various layers and ages of rock formations. These formations slope gently down toward the east, and consist of, in ascending order, predominantly crystalline rocks of the Precambrian Era, Cambrian through Devonian Period sedimentary rocks of the Paleozoic Era, and unconsolidated surficial deposits.

Sand and gravel, dolomite building stone and crushed aggregate, and organic material are the three principal mineral and organic resources in the Menomonee River watershed that have or have had significant commercial value as a result of their quantity, quality, and location. The commercial utilization of the watershed's mineral resources, which is limited to the mining of nonmetal deposits, is primarily directed toward supplying the construction materials for the continuing development of the Menomonee River watershed. The Menomonee River watershed contains 23 inactive sand and gravel pits and dolomite quarries, some of which have the potential to serve a variety of the needs in the ever-expanding urban area.

A wide variety of soil types occur within the watershed. Under a detailed soil survey, soil types have been mapped for 115 square miles, or 85 percent of the watershed; their physical, chemical, and biological properties identified; and interpretations made for planning purposes. Soil survey data and interpretations reveal that 23 square miles, or about 20 percent of the portion of the watershed for which soils data are available, are covered by soils poorly suited for residential development even with public sanitary sewer service. Approximately 93 square miles, or about 81 percent of the portion of the watershed for which soils data are available, are poorly suited for residential development without public sanitary sewer service on lots smaller than one acre in size. About 51 square miles, or approximately 44 percent of the portion of the watershed for which soils data are available, are poorly suited for residential development without public sanitary sewer service on lots one acre or larger in size.

Remaining prime agricultural lands are located in the headwater areas of the watershed along the Little Menomonee River, where they cover 13.9 square miles, or only about 10 percent of the watershed land area. These remaining prime agricultural lands are being threatened by urbanization occurring as small clusters of residential development.

The quantity and quality of watershed vegetation—woodlands and wetlands—is at any given point in time determined by, or the result of, numerous influences including climate, topography, glacial history, occurrence of fire, soil characteristics, proximity of bedrock, drainage features, and especially the activities of man. Prior to arrival of European settlers, the vegetation of the watershed consisted primarily of two terrestrial plant community types: medium wet upland forests composed of upland deciduous hardwoods, and floodland hardwood forests. Only very small remnants of woodlands and wetlands—3.2 square miles or 2 percent of the watershed area—still exist in the Menomonee River watershed.

Streams and associated floodlands comprise the most important element of the natural resource base of the watershed, primarily because of the associated aesthetic, recreational, and economic values. There are 68.6 lineal miles of perennial streams within the watershed, and inasmuch as there are no major lakes of 50 acres or more in size in the watershed, these streams constitute the watershed's surface water resources. Although the delineation of floodlands along the watershed stream system is extremely important to sound planning and development, precise floodland delineations were not, until the conduct of this study, available for the Menomonee River watershed.

Extensive groundwater resources underlie the Menomonee River watershed and are an integral part of the much larger groundwater system that lies beneath the Southeastern Wisconsin Planning Region. The aquifers lying beneath the watershed, which attain a combined thickness in excess of 2,200 feet, may be subdivided so as to identify three distinct groundwater sources. In order from the land surface downward they are the sand and gravel deposits in glacial drift, the shallow dolomite strata in the underlying bedrock, and the deeper bedrock strata composed of sandstone, dolomite, siltstone, and shale. The combined groundwater reservoirs are the source of water supply for many industries and for approximately 20 percent of the people residing in the watershed.

The remaining fish and wildlife resources are particularly significant to the urban and urbanizing Menomonee River watershed because of their recreational, educational, and aesthetic values, and because of the element of naturalness and diversity that they impart to the urban environment. Fish shocking studies indicate that the existing watershed fishery is marginal because of low oxygen levels and small streamflows, and currently has little value for sport-fishing purposes.

There are a total of 243 park, outdoor recreation, and related open space sites within the watershed, totaling 6,138 acres, or about 7 percent of the watershed area. A watershed-wide inventory revealed the existence of 18 potential recreation and related open space sites, with three of these rated as having high recreational resource value.

The delineation of selected natural resource and natural resource related elements on a watershed map produces an essentially lineal pattern encompassed in narrow, elongated areas which have been termed environmental corridors by the Southeastern Wisconsin Regional Planning Commission. As of 1964, primary environmental corridors occupied approximately 18 square miles, or 15 percent of the watershed area, and contained almost all of the remaining high value wildlife habitat areas and woodlands; most of the wetlands, lakes and streams, and associated floodlands; as well as many significant physiographic features and historic sites. The primary environmental corridors as originally delineated were a composite of the best of the individual elements comprising the natural resource base of the Menomonee River watershed. Although less than a decade has passed since these corridors were first identified, a considerable encroachment of urban development into the corridor has already occurred. The preservation of the remaining primary environmental corridors in a natural state or in park and related open space uses is essential to maintaining a high level of environmental quality in the Menomonee River watershed.

Chapter IV

ANTICIPATED GROWTH AND CHANGE IN THE MENOMONEE RIVER WATERSHED

INTRODUCTION

In any planning effort, forecasts are required of all future events and conditions which are considered to lie outside the scope of the plans to be prepared, but which affect either the design of the plan or its implementation. Normally, the future demand for land and water resources in a planning area is determined primarily by the size and spatial distribution of future population and employment levels. Although the spatial distribution of future population and employment levels can be influenced by public land use regulation, control of changes in population and economic activity levels per se lies largely outside the scope of governmental activity at regional and local levels. In the preparation of a comprehensive watershed plan, therefore, future population and economic activity levels must be forecast. These forecasts can then be converted to future demand for land and water resources within the watershed, and a land and water use plan can be prepared to meet this demand.

POPULATION AND ECONOMIC ACTIVITY

Forecasts of future population and economic activity within the Menomonee River watershed must consider the setting of the watershed within the urbanizing Southeastern Wisconsin Region. Forecasts also must consider the geographic and political features, the present pattern of historic trends, and the distribution of the population and economic activity within the watershed. As indicated in Chapter III, while the City of Milwaukee contains only about one-fifth of the watershed area, the city contains almost one-half of the watershed population. Population growth and changes in that portion of the watershed lying outside the City of Milwaukee are strongly influenced by the City, while economic activity in this entire watershed is heavily dependent upon employment in the City of Milwaukee and the Milwaukee urbanized area.

Population Forecast

Population forecasts for the Region and for the Menomonee River watershed have been prepared by the Commission to the year 2000. These forecasts are based upon economic, as well as demographic, studies and analyses using several independent methods.[1] Given a continuation of existing trends in population and employment growth and change, the population of the Region may be expected, as shown in Figure 16, to reach a year 2000 level of approximately 2,219,300 persons, an increase of about 463,200 persons, or 26 percent, over the 1970 level of 1,756,086.

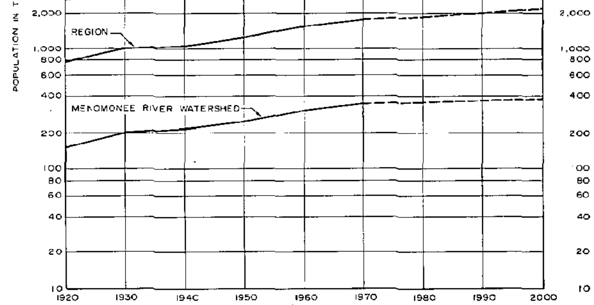
[1] *See SEWRPC Technical Report No. 11, The Population of Southeastern Wisconsin, December 1972.*

As indicated in Table 22, the population of the Menomonee River watershed has increased steadily from a level of about 151,000 persons in 1920 to about 348,000 persons in 1970, an increase over the 50-year period of about 130 percent. This level may be expected to increase by about 40,000 persons to about 388,000 persons by 2000, or by an additional 11 percent.

Although the forecast population levels represent a quite moderate rate of growth for the watershed, a review of the historic relationship between population growth in the watershed and population growth in the Southeastern Wisconsin Region indicates the forecast levels to be reasonable. Historically, the watershed has consistently comprised from 19 to 20 percent of the total regional population. The watershed is, however, expected to account for a decreasing proportion of the total regional population, decreasing from 20 percent in 1970 to 17.5 percent by 2000. This anticipated decline in the proportion of the total regional population located within the Menomonee River watershed reflects a continuation of present regional development trends that tend to concentrate new urban development in areas to the southwest

Figure 16

POPULATION TRENDS AND FORECASTS FOR THE UNITED STATES, WISCONSIN, THE REGION, AND THE MENOMONEE RIVER WATERSHED: 1920-2000



Source: U. S. Bureau of the Census, and SEWRPC.

and northeast of the middle and lower reaches of the Menomonee River watershed. The upper reaches of the watershed will continue to be part of the expanding Milwaukee urbanized area.

Economic Forecasts

Economic activity, considered primarily in terms of employment opportunities, is not functionally linked to watershed patterns within Southeastern Wisconsin. Rather, the forces from which economic activity originates and is sustained largely lie outside of the watershed itself. Much of the watershed, particularly the middle and upper portions, may be expected to continue to serve as a "dormitory" or "bedroom" area for many of the workers in the industrial complex of the lower portion of the watershed. The watershed may also be expected to continue providing the locations for new and expanding industrial and commercial enterprises seeking location in the peripheral areas of the Milwaukee urbanized area. Many of these peripheral locations are suburban areas in the middle and upper portions of the watershed. In addition, while the agricultural portion of the watershed economy may be anticipated to be less labor intensive in nature, it will continue to serve many demands of the local market area in and around the Milwaukee urbanized area. Therefore, the economy of the watershed may be expected to grow at approximately the same rate as that of the Region. As shown on Table 23, employment opportunities within the watershed may be expected to increase by about 48,200 jobs, or 28 percent, in the next 28 years; from 170,600 jobs in 1972 to 218,800 in 2000.

LAND USE DEMAND

The requirements of approximately 388,200 residents for homes and supporting community facilities will largely determine the amount and variety of the various land

Table 22

POPULATION TRENDS AND FORECASTS FOR THE UNITED STATES, WISCONSIN, THE REGION, AND THE MENOMONEE RIVER WATERSHED: SELECTED YEARS 1920-2000

Year	United States	Wisconsin	Region	Watershed	Watershed Population as Percentage of Regional Population
1920	105,710,620	2,632,067	783,681	151,271	19.3
1930	122,775,046	2,939,006	1,006,118	200,403	19.9
1940	131,669,270	3,137,587	1,067,699	213,295	20.0
1950	151,325,798	3,434,575	1,240,618	245,695	19.8
1960	179,323,175	3,952,771	1,573,620	309,240	19.6
1970	203,212,000	4,417,731	1,756,086	348,165	19.8
1980	220,664,000	4,600,000	1,873,400	350,100	18.7
1990	237,678,000	4,800,000	2,043,900	354,000	17.3
2000	254,502,000	5,100,000	2,219,300	388,214	17.5
1970-2000 Percentage Increase	25.2	15.4	26.4	11.5	--

Source: U. S. Bureau of the Census and SEWRPC.

Table 23

EXISTING AND FORECAST EMPLOYMENT WITHIN MENOMONEE RIVER WATERSHED AND THE REGION: 1972 and 2000

Area	Estimated 1972 Employment	Forecast 2000 Employment	Change 1972 to 2000	
			Absolute	Percent
Menomonee River Watershed.	170,600	218,800	48,200	28.2
Southeastern Wisconsin Region	749,000	1,015,200	266,200	35.5

Source: SEWRPC.

uses within the Menomonee River watershed in 2000. If present trends continue, it is probable that the approximately 40,000 new residents which the watershed may be expected to gain between 1970 and 2000 will live primarily in residential areas developed at medium densities. Of the 40,000 new residents, approximately one third may be expected to live in residential areas developed at low densities, and these residents will need nearly 64 percent of the newly developed residential land.

An analysis of urban development within the watershed from 1963 to 1970 indicates that about 64 percent of the land developed for residential use during this period consisted of low density development; nearly 36 percent consisted of medium density development, and less than 1 percent consisted of high density development.[2] However, in considering the number of new households added to the watershed from 1963 to 1970, less than 32 percent was located in low density areas, while 66 percent was located in medium density areas and about 1 percent was located in high density areas. The high proportion of new medium density and high density households in the watershed compared with the Region as a whole reflects, in part, the greater predominance of such development within the watershed than within the Region.

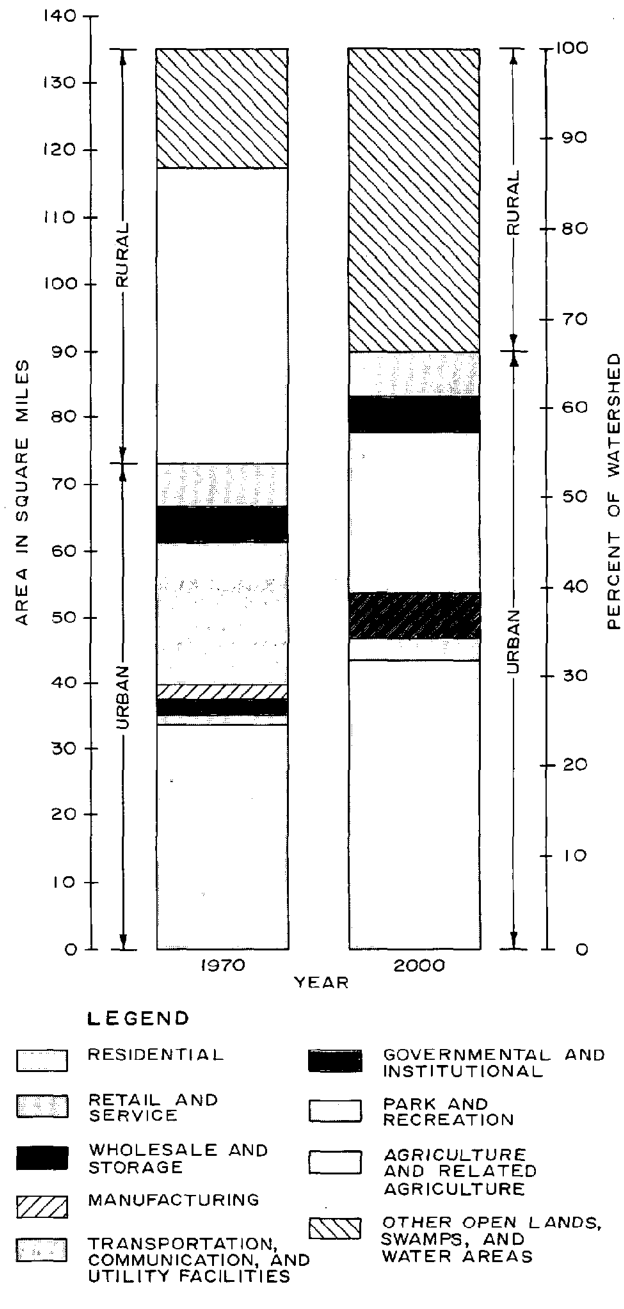
The analysis further indicates that, for the Region as a whole, about 98 percent of the population resides in households, with an average household size in 1970 of 3.20 persons. The remaining approximately 2 percent of the population reside in group quarters such as dormitories and boarding houses, or are inmates of institutions. For land use demand forecast purposes, it was assumed that the population increase in the watershed from 1970 to 2000 would reside in households with an average household size of 2.90 persons. It was further assumed that if existing trends (1963-1970) continue, approximately 33 percent of the new households within the watershed would locate in low density residential areas, or about 4,550 households; that 66 percent would locate in medium density residential areas, or about 9,100 households; and that 1 percent would locate in high density residential areas, or about 138 households.

Commercial and manufacturing land use demands also were forecast using the land-use-to-employee ratios established in the regional land use-transportation study of five commercial acres and seven manufacturing acres per 100 additional employees. Transportation and utility land use demand was forecast to increase in direct proportion to increases in residential use. This increase in the demand, for transportation and utility land use category was forecast as equaling 55, 25, and 11 acres per 1,000 additional people for the low, medium, and high residential density classes, respectively. Recreational land use demand and governmental and institutional land use demand were forecast using a land-use-to-population ratio of 14 acres and 9 acres, respectively, per 1,000 additional persons. Future agricultural and water, woodland, and wetland demands were not forecast since these uses within the watershed generally provide the area for expansion of the other land uses.

[2] *Low density residential development is defined as development having an overall average density of 1.2 dwelling units (households) per net residential acre; medium density as 4.3 dwelling units per net residential acre; and high density as 12.0 dwelling units per net residential acre.*

Figure 17

PROJECTED LAND USE DEMAND IN THE MENOMONEE RIVER WATERSHED: 2000



Source: SEWRPC.

Table 24

PROJECTED LAND USE DEMAND IN THE MENOMONEE RIVER WATERSHED: 2000

Land Use Category	1970 Area in Square Miles	1970 Percent of Watershed	1970 Percent of Major Category	Incremental Land Use Demand 1970-2000 Area in Square Miles	Incremental Land Use Demand 1970-2000 Percent of Major Category	2000 Area in Square Miles	2000 Percent of Watershed	2000 Percent of Major Category
Urban								
Residential[a]								
Low Density	15.78[b]	11.64	21.71	5.83	33.46	21.61	15.93	23.98
Medium Density	10.89[c]	8.03	14.99	3.27	18.76	14.16	10.44	15.72
High Density	7.22[d]	5.32	9.94	0.02	0.11	7.24	5.34	8.04
Subtotal	33.89	24.99	46.64	9.12	52.33	43.01	36.30	51.12
Retail and Service	1.77	1.31	2.44	1.67	9.58	3.44	2.54	3.82
Wholesale and Storage	1.55	1.14	2.13	3.01	17.27	6.83	5.04	7.58
Manufacturing	2.27	1.67	3.12					
Transportation, Communications, and Utility Facilities . . .	22.21	16.38	30.56	2.19	12.56	24.40	17.99	27.08
Governmental and Institutional	5.02	3.70	6.91	0.56	3.21	5.58	4.11	6.19
Park and Recreation.	5.96	4.39	8.20	0.88	5.05	6.84	5.04	7.59
Total Urban Land Use	72.67	53.58	100.00	17.43	100.00	90.10	66.43	100.00
Rural								
Agricultural and Related	45.11	33.26	71.65	- 17.43	100.00	45.53	33.57	100.00
Other Open Land Swamps and Water Areas	17.85	13.16	28.35					
Total Rural Land Use	62.96	46.42	100.00	- 17.43	100.00	45.53	33.57	100.00
Total Land Use	135.63[e]	100.00	--	--	--	135.63	100.00	--

[a] *The net residential density classes are as follows: low, 0.2-2.2 dwelling units per net residential acre; medium, 2.3-6.9 dwelling units per net residential acre; and high, 7.0-17.9 dwelling units per net residential acre.*

[b] *The 1970 under development land use category for low density residential land use totals 2.04 square miles and is included in this total.*

[c] *The 1970 under development land use category for medium density residential land use totals 1.11 square miles and is included in this total.*

[d] *The 1970 under development land use category for high density residential land use totals 0.03 square miles and is included in this total.*

[e] *This figure represents the total area of the watershed as determined through approximating the watershed boundary by U. S. Public Land Survey quarter section and summing the quarter section totals. The actual measured watershed total is 137.23 square miles, or 87,827.20 acres, representing a difference of 1.60 square miles, or about 1,024 acres, from the approximated watershed total.*

Source: SEWRPC.

Based upon the foregoing assumptions and the population forecast for the watershed, the 2000 demand within the watershed for the major land use categories was projected as shown in Table 24 and Figure 17. Comparison with existing land use data indicates that the continuation of present residential land development trends within the watershed may be expected to result in an increase in residential land use from about 34 square miles in 1970 to about 43 square miles in 2000, an increase of about 26 percent. All other urban land uses may be expected to increase from a total of about 39 square miles in 1970 to over 47 square miles in 2000, or by about 21 percent. Total urban land use is projected to increase from 73 square miles in 1970 to 90 square miles in the year 2000, an increase of 17 square miles or 23 percent. This total demand for urban land will have to be satisfied primarily through the conversion to urban use of existing watershed-agricultural lands, woodlands, and unused lands. These lands may be expected to decline collectively by over 17 square miles, or approximately 28 percent.

SUMMARY

It is estimated that the population of the Menomonee River watershed will increase from the 1970 level of over 348,000 persons to a 2000 level of about 388,000 persons, an increase of over 40,000 persons, or 11.5 percent. Over the 28-year period from 1972 to 2000, the number of jobs may be expected to increase by about 48,200, or about 28 percent, from about 170,600 in 1972 to about 218,800 in 2000. The population of the watershed also is expected to share in the increased levels of income, educational achievement, and leisure forecast for the Region in general.

If present trends in urban development within the watershed continue, residential land use may be expected to increase by about 26 percent, from about 34 square miles in 1970 to about 43 square miles in 2000, and supporting urban land uses may increase by about 21 percent, from about 39 square miles in 1970 to over 47 square miles in 2000. The projected sprawl of residential land—an addition of over 9 square miles between now and 2000 to accommodate 40,000 persons—will be primarily devoted to new low density development. Although this development will house less than 33 percent of the new households, it will occupy about 5.8 square miles and account for 64 percent of the land to be converted from rural to residential use. The expansion of urban development within the watershed under projected conditions would require, in turn, conversion of over 17 square miles, or about 28 percent, of the existing open land resources of the watershed.

Chapter V

HYDROLOGY AND HYDRAULICS

INTRODUCTION

Hydrology may be defined as the study of the physical behavior of the water resource from its occurrence as precipitation to its entry into streams and lakes or its return to the atmosphere via evapotranspiration.[1] In accordance with this definition, an inventory and analysis of the hydrology of a watershed includes consideration of precipitation, evapotranspiration, and other elements of the hydrologic budget; examination of factors such as soil types and land use that affect rainfall-runoff relationships; review of stream gaging records to ascertain the volume and timing of that portion of the precipitation that ultimately reaches the surface water system of the watershed as runoff; and determination of the volume of water that moves to and from and is contained within the aquifers[2] lying beneath the watershed.

Hydraulics may be defined as the inventory and analysis of those factors that affect the physical behavior of water as it flows within stream channels and associated natural floodlands; under and over bridges, culverts and dams; through lakes and other impoundments, and within the aquifer system of the watershed. In accordance with this definition, an inventory and analysis of the hydraulics of a watershed include examination of the length, slope, flow resistance, and other characteristics of both natural and modified stream reaches within the watershed; determination of the hydraulic significance of the numerous and varied hydraulic structures—bridges, culverts, dams, channelized sections—located throughout the stream system; and determination of the flow characteristics of the aquifers underlying the watershed.

Comprehensive planning for the wise use and development of the land and water resources of the Menomonee River watershed requires knowledge and understanding of the relationships existing among the many natural and man-made features that together comprise the hydrologic-hydraulic system[3] of the watershed. The objective of this chapter is to present a comprehensive and detailed description of the Menomonee River watershed hydrologic-hydraulic system and its behavioral characteristics pertinent to comprehensive watershed planning. An understanding of this system is of utmost importance to the Menomonee River watershed planning program inasmuch as the system and the processes that occur therein form the framework within which all the water resource and water resource-related problems of the watershed must be analyzed and resolved. Because of the interdependence of land use and surface and groundwater quality and quantity, any planned modification to, or development of, one element of the hydrologic-hydraulic system must consider the potential results and effects on all other elements of the system. Only by considering the hydrologic-hydraulic system as a whole can a sound, comprehensive watershed plan be prepared and the water-related problems of the basin be ultimately abated.

Digital computer simulation was used in the Menomonee River watershed study to accomplish the necessary integrated analysis of the watershed hydrologic-hydraulic system. The primary purpose of inventorying and analyzing the hydrologic and hydraulic data and information as presented in this chapter was to provide the input required by the hydrologic-hydraulic simulation model.

HYDROLOGY OF THE WATERSHED

The Hydrologic Cycle

The quantity and quality of water at a particular location within the Menomonee River watershed may vary greatly from time to time. These variations may occur rapidly or slowly and may occur in the atmosphere, on the land surface, in the surface waters, or in the groundwater of the watershed. Moreover, these variations may involve water in all its states—solid, liquid, and vapor. This continuous, unsteady pattern of circulation of the water resource from the atmosphere to and under the land surface and, by various processes, back to the atmosphere, is known as the hydrologic cycle.

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[1] *Evaporation is the process whereby water is transformed from the liquid or solid state to the vapor state and returned to the atmosphere. Transpiration is the process by which water in the liquid state moves up through plants, is transformed to the vapor state and returned to the atmosphere. Evapotranspiration is the sum of the two processes and, on an annual basis, accounts for about 72 percent of the precipitation that falls on the Menomonee River watershed.*

[2] *An aquifer is a porous water-bearing geologic formation. As used herein it is a relative term designating geologic formations, or deposits, that contain significant amounts of groundwater which can be used as a principal source of water supply.*

[3] *A system may be defined as a set of interdependent physical units and processes that functions in a predictable, regular manner. Physical units in a watershed hydrologic-hydraulic system include, but are not limited to, the numerous small subbasins, into which the watershed may be divided and the individual channel catchments, or reaches, including associated impoundment areas, in the watershed. Examples of processes in the watershed hydrologic-hydraulic system are subbasin rainfall-runoff relations and hydrograph attenuation in channels and reservoirs.*

Precipitation is the primary source of all water in the Menomonee River watershed. Part of the precipitation runs directly off the land surface into stream channels and is ultimately discharged from the watershed; part is temporarily retained in snow packs, ponds and wetlands, in the soil, or on vegetation and is subsequently transpired or evaporated; while the remainder is retained in the soil or passed through the soil into a zone of saturation or groundwater reservoir. Some water is retained in the groundwater system; but in the absence of groundwater development, much eventually returns to the surface as seepage or spring discharge into ponds and surface channels. This discharge constitutes the entire natural flow of most streams in the Menomonee River watershed during extended periods of dry weather.

With the exception of the groundwater in the deep sandstone aquifer underlying the watershed, all of the water on the land surface and underlying the Menomonee River basin generally remains an active part of the hydrologic system. In the deep aquifer, water is held in storage beneath the nearly watertight Maquoketa shale formation and is, therefore, taken into the hydrologic cycle in only a very limited way. Since the deep aquifer recharge area lies entirely west of the Menomonee River watershed, artificial movement through wells and minor amounts of leakage through the shale beds provide the only connection between this water and the surface water and shallow groundwater resources of the watershed.

The Water Budget: Quantification of the Hydrologic Cycle

A quantitative statement of the hydrologic cycle, termed the water budget, is commonly used to equate the total gain, loss, and change in storage of the water resource in a watershed over a given time period. Water is gained by a basin from precipitation and subsurface inflow, while water loss occurs as a result of evaporation, transpiration, and surface and subsurface outflow. A change in surface and groundwater storage results from an imbalance between inflow and outflow. The principal value of the hydrologic budget is that it indicates how much water exists within a watershed.

The complete hydrologic budget applicable to a watershed for any time interval may be expressed by the equation

$$P - GW - E - T - R = S$$

in which the individual terms are volumes expressed in inches of water over the entire area of the watershed and are defined as follows:

- P = precipitation on the watershed
- GW = net inflow or outflow of groundwater from the aquifer beneath the watershed
- E = evaporation from the watershed
- T = transpiration from the watershed
- R = runoff from the watershed measured as streamflow
- S = net change in total surface and groundwater storage

Quantitative data, however, are normally available for only a few of the elements in the hydrologic budget. Quantitative measurements, or estimates, compiled for the Menomonee River watershed include precipitation, streamflow, evaporation, and groundwater levels; but the records of even these phenomena are incomplete and of a relatively short duration. It is necessary, therefore, to express the hydrologic budget on an average annual water-year basis in a simplified form which includes the significant components of the hydrologic cycle but excludes those components for which sufficient data are not available. A water-year time frame—October 1 of a given year through September 30 of the following year—is used because the beginning and end of that period normally corresponds to low and stable streamflows and groundwater levels. Moreover, since water in the deep sandstone aquifer is taken into the hydrologic cycle in only a very limited way, a hydrologic budget for the Menomonee River watershed can be developed considering only the surface and shallow groundwater supplies.

In its simplest form, then, the long-term hydrologic budget for the Menomonee River watershed may be expressed by the equation

$$ET = P - R$$

where evaporation and transpiration have been combined into one variable, ET, denoting evapotranspiration because of the difficulty of distinguishing between these two elements of the budget, and where net groundwater flow out of the watershed has been assumed to be zero, as has the net change in the total surface and groundwater stored within the watershed. It is recognized that because of seasonal variations in the behavior of the phases of the hydrologic cycle, this simplified equation is not generally valid for time durations of less than a year.

As stated in Chapter 3 of this report, the average annual precipitation over the watershed is 29.1 inches. Streamflow records for the U. S. Geological Survey gaging station on the Menomonee River at Wauwatosa, indicate that the average annual runoff from the watershed is 8.2 inches based on 12 water years of record extending from October 1, 1961, through September 30, 1973. Substitution of these values for precipitation and runoff into the simplified hydrologic budget equation indicates an average annual evapotranspiration of 20.9 inches. On an average annual water-year basis, therefore, about 72 percent of the precipitation that falls on the Menomonee River watershed is returned to the atmosphere by the evapotranspiration process while the remaining 28 percent leaves the watershed as streamflow.

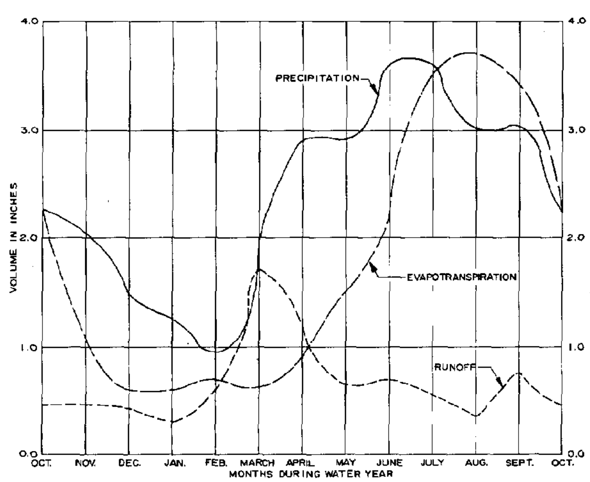
While it is not possible, as already noted, to develop a complete hydrologic budget for the Menomonee River watershed for time intervals shorter than a water-year, it is feasible and instructive to examine the monthly variation of certain elements of the hydrologic budget for which average monthly values may be estimated or determined by measurement. The monthly distribution of three such elements—precipitation, evapotranspiration, and runoff—in the Menomonee River watershed is presented in Figure 18. Monthly precipitation and runoff values are based on actual measurements, whereas monthly evapotranspiration values are estimates developed by using monthly potential evaporation data to distribute the annual evapotranspiration—as determined by the hydrologic budget—for the watershed.

The distributional pattern of precipitation in the watershed, as shown in the figure, results in the lowest values of precipitation occurring during mid-winter and the highest values during mid-summer. Although annual runoff is directly proportional to precipitation, its monthly or seasonal distribution does not closely follow the precipitation pattern. For example, the peak runoff months are March and April, which closely follow the minimum precipitation months of January and February and occur before, rather than after, the peak precipitation months of June and July. This apparent inconsistency may be explained by the fact that the runoff occurring in March and April consists of rainfall in combination with melt water from snow and ice accumulated over the winter season. High streamflows do not generally occur subsequent to the June-July period of high precipitation, because evapotranspiration rates reach yearly high and because, as shown on Figure 18, during this season a higher proportion of precipitation infiltrates to groundwater storage, appearing later as base flow.

In summary, then, rainfall and runoff do not follow similar patterns when viewed on a monthly basis during the water year because of two factors: the rapid release in spring, as temperatures rise, of large quantities of water accumulated over the winter in the form of snow and ice,

Figure 18

MONTHLY DISTRIBUTION OF PRECIPITATION, RUNOFF, AND EVAPOTRANSPIRATION IN THE MENOMONEE RIVER WATERSHED



Source: U. S. Geological Survey, National Weather Service, and SEWRPC.

and the high evapotranspiration rates that prevail during the summer growing season. Consequently, whereas almost half of the average annual runoff occurs during the two months of March and April, less than one-fifth of the average annual precipitation occurs during that period.

Atmospheric Phase of the Hydrologic Cycle

The processes of precipitation and evapotranspiration constitute the atmospheric phase of the hydrologic cycle of the Menomonee River watershed. On a water-year basis, precipitation accounts for essentially all the water entering the watershed while evapotranspiration is the process by which most of the water leaves the watershed.

Precipitation: The average annual total precipitation for the Menomonee River watershed based on a Thiessen polygon network analysis of data from nine observation stations located in or near the watershed is 29.1 inches—distributed on a monthly basis as shown in Figure 18—whereas the average annual snow and sleet fall is 42.0 inches measured as snow and sleet. The location of these nine stations—three of which lie within the watershed and six of which lie outside of it—as well as the types of precipitation-recording equipment and the availability of temperature and other meteorological data are shown on Map 28 and Table 25. Additional information about selected stations is presented in Chapter VIII.

Monthly total precipitation values as well as monthly snow and sleet fall quantities for the above nine stations are presented in tabular form and discussed in Chapter III, "Description of the Watershed." That chapter also includes a discussion of the significance of precipitation data in the watershed planning process, and it includes information on precipitation-related climatic factors such as temperature, snow cover, and frost depth. Chapter II, Volume 2, "Watershed Development Objectives, Principles and Standards," discusses the results of various statistical analyses of the basic precipitation data with the results being presented in graphical and tabular form in an appendix of Volume 2 of this report. That appendix includes point rainfall-intensity-duration-frequency relationships in both graphical and tabular form, point rainfall depth-duration-frequency curves, and depth-duration area curves.

Evapotranspiration: Annual evaporation from water surfaces, such as ponds and streams, within the Menomonee River watershed is about 29 inches and, therefore, approximately equal to the average annual precipitation of 29.1 inches. The average annual evapotranspiration, as calculated in the hydrologic budget for the watershed, is about 20.9 inches, or 153,000 acre-feet or 50 billion gallons per year. The 8.2 inch difference between the potential for evaporation from a free water surface and long-term evapotranspiration over the watershed occurs because evapotranspiration from soils and plants is, depending upon such factors as land use, temperature, available water, and soil conditions, normally less than evaporation from free water surfaces. The estimated monthly distribution of average annual evapotranspiration is shown in Figure 18.

Surface Water Phase of the Hydrologic Cycle

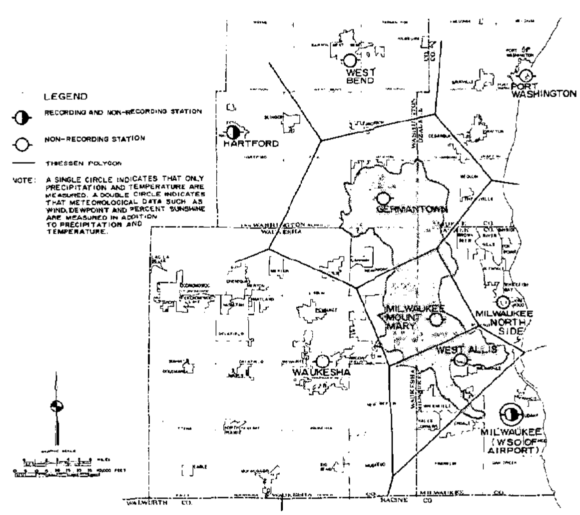
Surface water in the Menomonee River watershed is composed almost entirely of streamflow since, as indicated in Chapter III, there are no major lakes—that is lakes of 50 acres or more in surface area—located within the watershed. Wetlands, flooded gravel pits, and minor lakes and ponds comprise the balance of the surface water but are negligible relative to the amount of surface water occurring in the stream system of the watershed.

Monitoring Stations: Streamflow is unique among the various components of the hydrologic cycle in that it is the only component that is confined so as to pass a finite location and, therefore, amenable to relatively precise measurement of the total quantities present. As shown on Map 29, a variety of stream stage and discharge monitoring stations has been constructed and is operated in the watershed by the U. S. Geological Survey, the Milwaukee-Metropolitan Sewerage Commissions, the City of Milwaukee, and the Village of Menomonee Falls.

Streamflow is not measured directly, but is derived from measurements of "stage," that is, of water surface elevation at monitoring stations along a stream. In order to convert a measured stage to its corresponding discharge, a stage-discharge relationship must be developed for each monitoring site. Such relationships are normally constructed by making field measurements of discharge for a wide range of river stages. For each such stage, discharge is determined by partitioning the total flow cross-section

Map 28

METEOROLOGICAL STATIONS OF THE NATIONAL WEATHER SERVICE IN OR NEAR THE MENOMONEE RIVER WATERSHED: 1973



The Thiessen polygon network constructed for the nine U. S. Weather Bureau observation stations shown above was used to associate land areas with specific meteorological data. This was a necessary requirement for operation of the water resources simulation model used to calculate streamflow and stream water quality.

Source: National Weather Service and SEWRPC.

into subareas, using a meter to measure the flow velocity in each subarea, multiplying velocity times area for each subarea to obtain subarea discharge, and integrating over all subareas to obtain the total discharge.

Stage is determined by various types of indicators with the readings taken manually at intervals by an observer or recorded by automatic instruments. Stage indicators are classified according to the method by which the stage is measured and by the manner in which it is read. The principal types are staff gages, crest stage indicators, wire weight gages, and continuous recording gages. All have been, or are, used in the Menomonee River watershed.

A staff gage is used to measure the water level by direct observation. As shown on Figure 19, it consists simply of a graduated scale established in a stream—usually vertically—on a bridge pier or abutment, a wall or other structure or stable support. It is read by observing the elevation of the water surface in contact with the scale. Of the various types of stage gages, the staff gage is least costly to establish but has a significant disadvantage in that it does not automatically record the peak stage of a flood event or the time at which it occurred.

A crest stage gage is used to measure the peak stage during a flood event. As shown in Figure 20, it consists primarily of a pipe mounted vertically on a firm support near the stream. The pipe is closed at the top and bottom except for small holes at the bottom to permit water to enter and exit and small holes at the top to permit the free flow of air into and out of the gage. A graduated staff is positioned vertically inside of the gage. As the river rises during a flood event, water enters the holes at the bottom of the gage and rises inside the pipe as air exits from the holes at the top of the gage. Granular cork inside the gage floats on this rising water surface and adheres to the graduated staff at the peak flood stage. After the flood has passed, the crest stage gage is read by removing the screw cap at the top of the gage, lifting out the calibrated staff, and recording the elevation indicated by the cork. While the crest stage gage costs more than a staff gage, it has the advantage of measuring the actual peak flood stage although it does not indicate the time at which that stage occurred.

A wire weight gage, as shown in Figure 21, consists of a steel wire or cable—with a weight at one end—wound on a drum with the entire assembly enclosed within a protective housing that is mounted above the stream on a bridge or other structure. To measure river stage, a hand crank is used to unwind the drum so as to lower the weight to the water surface. The stage is determined by means of a combination of a mechanical counter driven by the revolving drum and a graduated scale on the periphery of the drum. With respect to the kind of information obtained, the wire weight gage is similar to the staff gage in that it does not automatically record either the peak stage of a flood event or the time at which that stage occurred.

A continuous recording gage, as shown in Figure 22, is an automated device that permits the sensing and recording of river stage on a continuous basis or at very short time

Table 25

NATIONAL WEATHER SERVICE METEOROLOGICAL STATIONS
IN AND NEAR THE MENOMONEE RIVER WATERSHED: 1973

Station Identification		Location				
Name	National Weather Service Number	Within Watershed	Outside of Watershed	County	City or Village	Current Location
Germantown	3058	x	--	Washington	Village of Germantown	Germantown North-STP
Milwaukee-Mount Mary	5474	x	--	Milwaukee	City of Milwaukee	Mount Mary College
West Allis	9046	x	--	Milwaukee	City of West Allis	Allis Chalmers Company
West Bend	9050	--	x	Washington	City of West Bend	Private Residence
Hartford	3453	--	x	Washington	City of Hartford	Hartford-STP
Waukesha	8937	--	x	Waukesha	City of Waukesha	Waukesha Water Utility
Port Washington	6764	--	x	Ozaukee	City of Port Washington	Wis. Electric Power Company
Milwaukee-North Side	5477	--	x	Milwaukee	City of Milwaukee	WISN-TV Station Tower
Milwaukee-NWS	5479	--	x	Milwaukee	City of Milwaukee	Terminal Building Mitchell Field

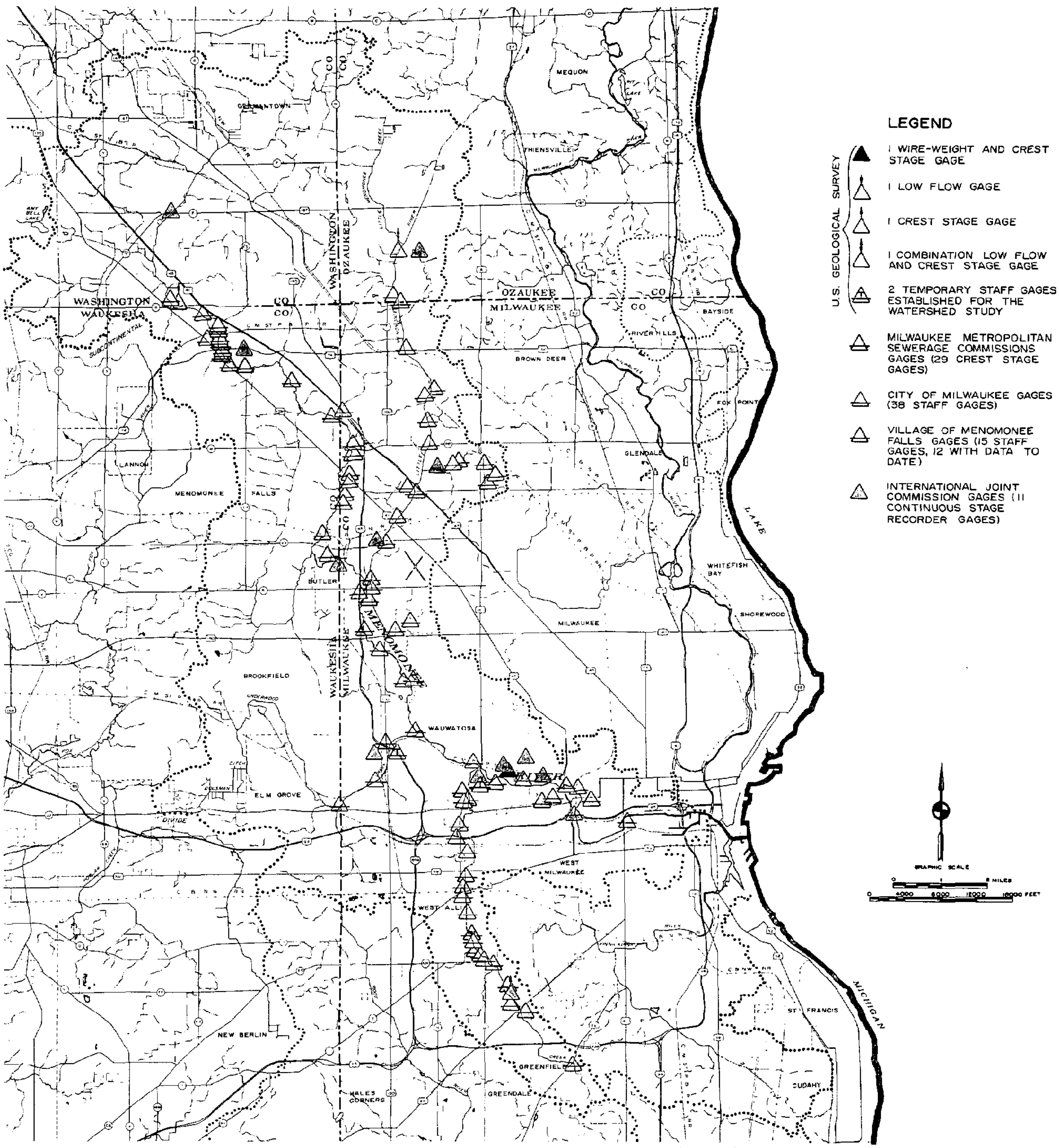
Source: *National Weather Service Report: Climatological Data, Wisconsin, Annual Summary 1973, and SEWRPC.*

increments such as five or fifteen minutes. Continuous recording stations consist of three major elements: a stage sensing device, a stage recording device, and a protective structure to house the equipment. The stage sensing device may be a float set in a stilling well and connected to the stage recording device by a tape or wire or the stage may be sensed by the pressure required to maintain a flow of gas through a small orifice submerged in the stream. The signal from the stage sensing device is relayed to the stage recording device which may consist of a strip chart recorder on which a pen plots a continuous record of stage or a punch tape recorder on which stage is recorded at predetermined intervals in the form of holes punched in a tape. The punched tape recording device permits computer processing of the stage data. The protective structure—which must be large enough to contain the equipment and permit ready access to it and which must be sturdy enough to prevent vandalism—may consist of vertically positioned concrete or corrugated metal pipe provided with a roof or may be of frame, prefabricated panel or masonry construction. The continuous recording gage, which is the most costly of the three basic types of stage monitoring installations, provides superior data in that both stage and time are continuously recorded for the full spectrum of flow conditions.

Although there is a large number of stage and discharge monitoring stations located in the watershed, relative to the size of the watershed, the overall existing monitoring system has, from a watershed planning perspective, several deficiencies. The monitoring stations are centralized in Milwaukee County rather than being distributed throughout the watershed; most stations provide only stage data, and only for extreme events; and the one daily flow gaging station does not provide for continuous recordation but must, instead, be read manually. As a result of the International Joint Commission (IJC) Menomonee River Pilot Watershed Study which was initiated in 1974, there were, at the end of 1975, eleven continuous recording stream gaging stations housed in semi-permanent structures in the Menomonee River watershed—three on intermittent streams and eight on the perennial stream system with one of the latter group being located at the site of the wire weight gage on the Menomonee River in

Map 29

STREAM STAGE AND DISCHARGE STATIONS IN THE MENOMONEE RIVER WATERSHED

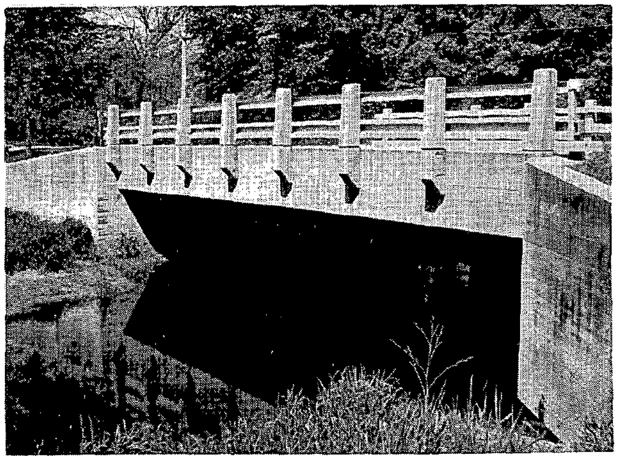


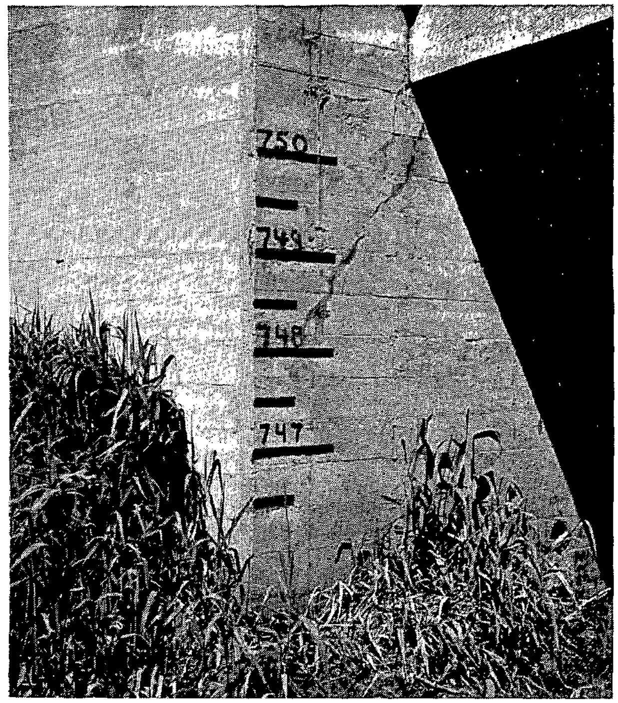
Streamflow is unique among the various components of the hydrologic cycle in that it is the only component that is concentrated and confined so as to pass a limited number of identifiable locations and, therefore, amenable to relatively accurate and precise measurement of the total quantities involved. As shown above, a variety of stream stage and discharge monitoring stations have been constructed and are operated in the watershed.

Source: SEWRPC.

Figure 19

TYPICAL STAFF GAGE



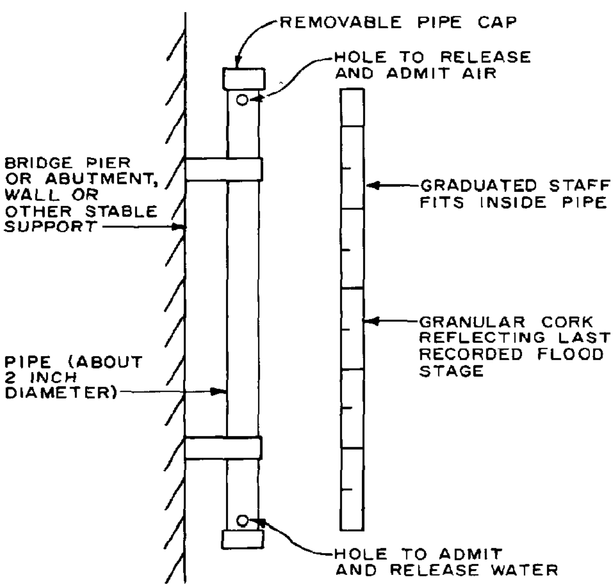


Staff gage located at the Lilly Road crossing of the upper Menomonee River in the Menomonee River watershed. Gage is read in feet above mean sea level datum.

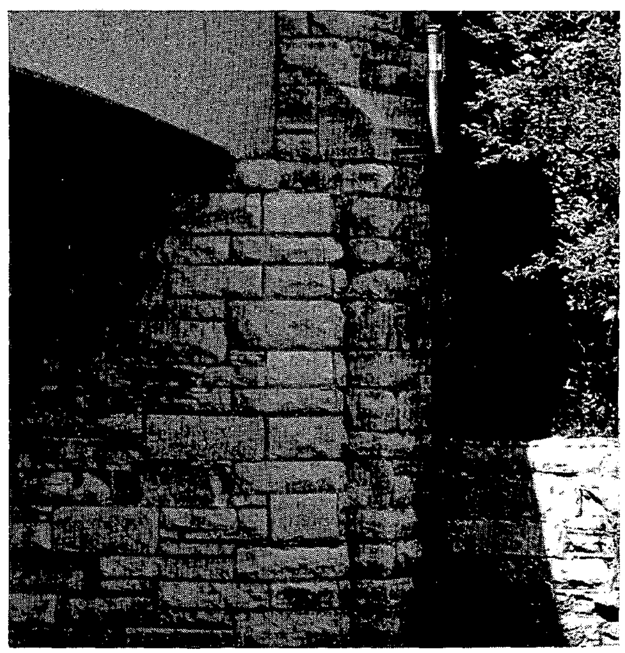
Source: SEWRPC.

Figure 20

TYPICAL CREST STAGE GAGE



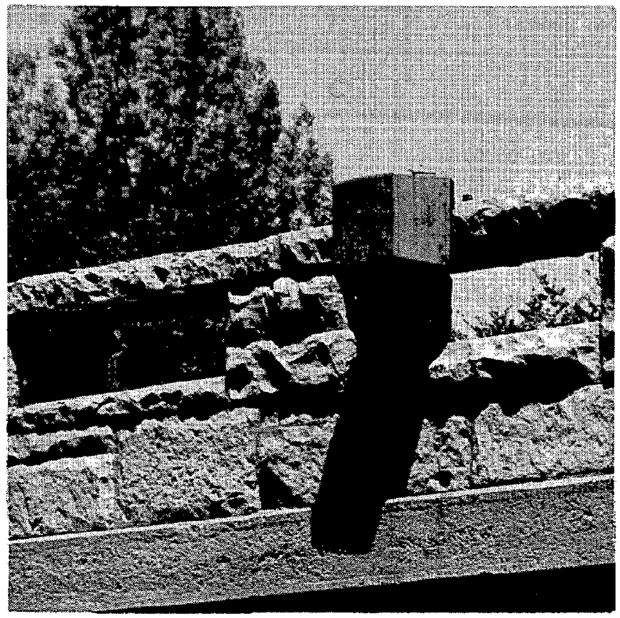
Source: U. S. Geological Survey and SEWRPC.



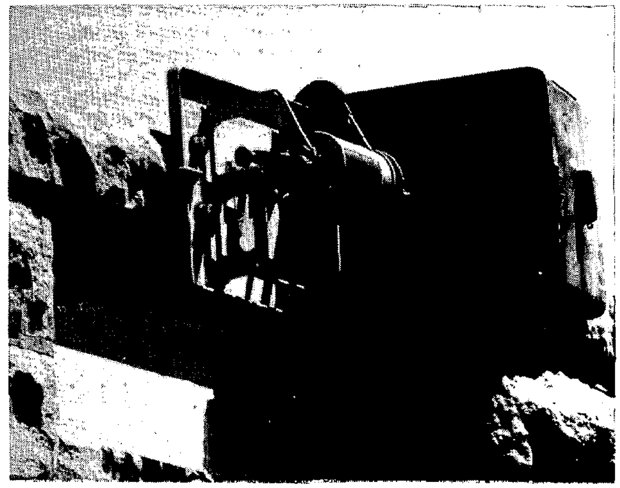
Crest stage gage located at the 70th Street crossing of the lower Menomonee River in the Menomonee River watershed.

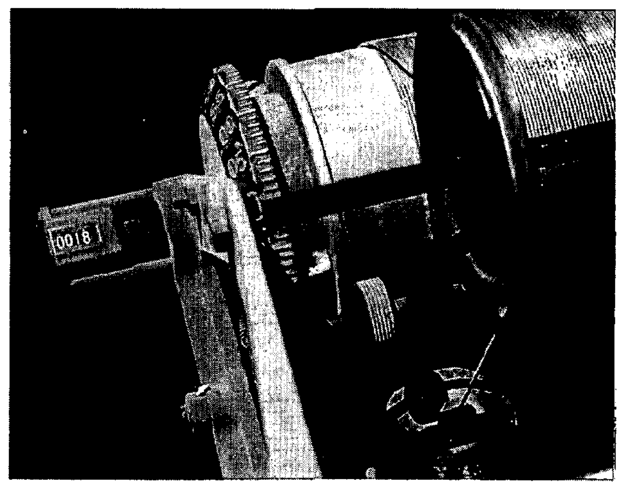
Figure 21

TYPICAL WIRE WEIGHT GAGE

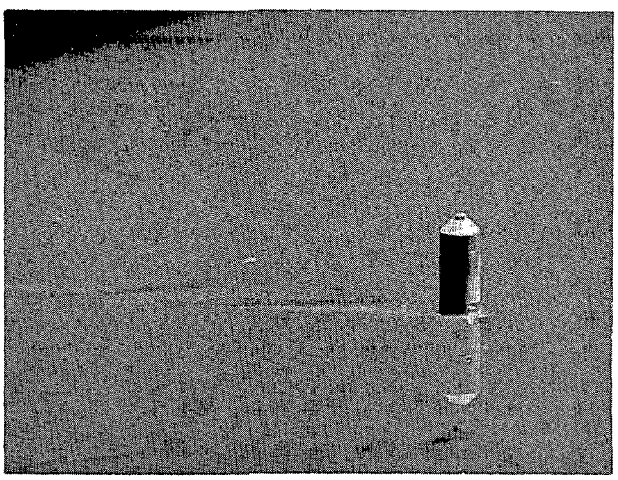


Gage Housing Mounted on Bridge Rail





Drum, Wire, and Weight Inside Gage Housing



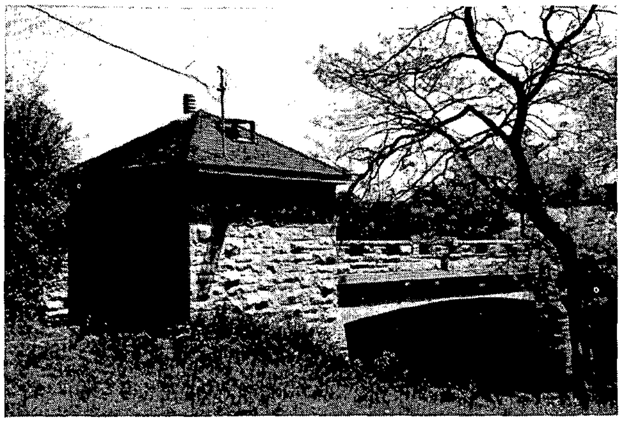
Wire-Weight Lowered to Water Surface During Stage Measurement

Wire-Weight Gage Located at the 70th Street Crossing of the lower Menomonee River

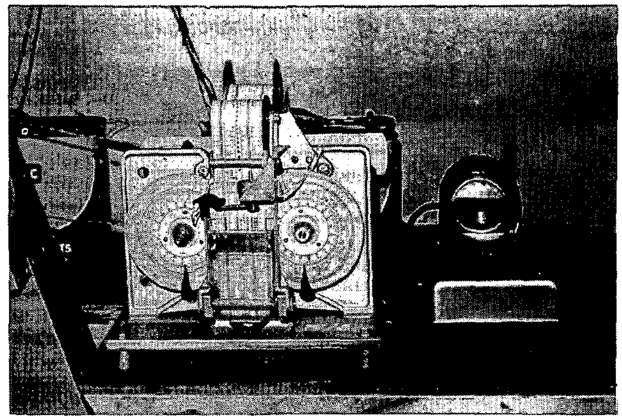
Source: U. S. Geological Survey and SEWRPC.

Figure 22

TYPICAL CONTINUOUS RECORDING GAGE



Protective structure housing the continuous recording installation located at the 70th Street crossing of the lower Menomonee River.



Punched tape stage recorder at the continuous recording station at the 70th Street crossing of the lower Menomonee River.

Source: U. S. Geological Survey and SEWRPC.

the City of Wauwatosa. This network of eleven continuous flow recordation gaging stations is operated by the U. S. Geological Survey as a participant in the IJC Menomonee River Pilot Watershed Study.

U. S. Geological Survey Stage and Discharge Stations: Some of the streamflow and related monitoring stations are maintained in the watershed stream system by the U. S. Geological Survey (USGS). Results of the observations at these stages are published by the USGS in a series of publications entitled "Water Resources Data for Wisconsin." A wire-weight gage (USGS Gage No. 4-0871.2, Wauwatosa) located at the N. 70th Street crossing of the Menomonee River has been operated by the USGS on a daily basis since October 1, 1961. This station monitors flow from a 123 square mile drainage area which comprises 89.8 percent of the total area of the watershed. Even though the period of record is short, daily discharge measurements at this gage constitute the principal source of data for characterizing streamflow of the Menomonee River watershed. All the other stage and discharge monitoring stations in the watershed are utilized only during either major flood events or unusual drought periods and, therefore, do not provide information about the full spectrum of stream stages and discharges that actually occurs.

A crest stage gage (USGS Gage No. 4-0871, Milwaukee) has been operated by the USGS since 1959 at the N. 70th Street crossing on Honey Creek in the City of Milwaukee. This station receives streamflow from a 3.34 square mile area which comprises 2.5 percent of the total area of the watershed. Instantaneous peak discharges are available for each water year in the period of record.

The USGS has maintained since 1962 a low flow gage (USGS Gage No. 4-0870.2, Menomonee Falls) on the Menomonee River at the Washington-Waukesha County Line. This station monitors streamflow from a 32.0 square mile area comprising 23.4 percent of the watershed area. Low flow measurements have been obtained at this site for each water year in the period of record except for 1968, 1970, 1971, and 1972.

A combination crest and low flow gage (USGS Gage No. 4-0870.5, Freistadt) has been operated by the USGS since 1958 at the Donges Bay Road crossing of the Little Menomonee River in the City of Mequon, Ozaukee County. This station receives surface water discharge from a 7.96 square mile rural area which comprises 5.8 percent of the watershed area. Instantaneous peak discharges are available for each water-year in the period of record while low flows have been obtained since 1961 for all water-years except 1968, 1970, 1971, and 1972.

While the four above stations are all operated by the USGS, they are funded on a cooperative basis by the USGS and two State of Wisconsin agencies. The wire-weight gage on the Menomonee River at Wauwatosa and the low flow gage on the Washington-Waukesha County line are cooperatively funded by the USGS and the Wisconsin Department of Natural Resources, whereas the USGS and the Wisconsin Department of Transportation cooperatively fund the crest stage gage on Honey Creek in the City of Milwaukee. The last of the four gages maintained by the USGS, the combination crest stage and low flow gage in the Little Menomonee River in the City of Mequon, is cooperatively funded by the USGS and the Wisconsin Departments of Natural Resources and Transportation.

Milwaukee-Metropolitan Sewerage Commissions Crest Stage Gages: A total of 29 crest stage gages is operated in the Milwaukee County portion of the Menomonee River watershed by the Milwaukee-Metropolitan Sewerage Commissions. These flood crest monitoring stations were installed in 1966 and 1967 and, as shown on Map 29, are rather uniformly distributed along the Menomonee River and three tributaries. Ten of the sites are on the Menomonee River, four are on the Little Menomonee River, three are on Underwood Creek, and the remaining twelve are on Honey Creek. In general, one or more flood crest measurements have been made at each of the 29 stations during each of the years for which the stations have been in existence.

Peak flood stage data from these 29 gages were used, as discussed in Chapter VI of this report, "Flood Characteristics and Damage," to develop historic flood stage profiles of the Menomonee River system. In addition to providing quantitative documentation of historic flooding, these flood stage profiles were also used, as discussed in Chapter VIII, "Water Resource Simulation Model," to calibrate the watershed hydrologic-hydraulic simulation model.

City of Milwaukee Staff Gages: A total of 38 staff gages is maintained by the City of Milwaukee in the Milwaukee portion of the watershed, as of 1973. This network of staff gages is monitored by field personnel during and after flood events. Thirteen of the monitoring sites are on the Menomonee River, nine are on the Little Menomonee River, nine are located on Honey Creek, five are on Noyes Creek, and two are on Grantosa Creek. In general, one or more flood stage elevations have been made at each of the 38 City of Milwaukee stations during each of the years that these stations have been in existence. The flood stages recorded at these staff gages were used, along with the Milwaukee-Metropolitan Sewerage Commission crest stage data, to develop historic flood stage profiles and to calibrate the watershed hydrologic-hydraulic simulation model.

Village of Menomonee Falls Staff Gages: Since May 1973 the Village of Menomonee Falls has monitored 14 staff gages along the Menomonee River reach within the Village at the locations shown on Map 29. Field personnel make stage observations at these sites during or immediately after periods of high water and normally one or more stage measurements have been made at each station during each of the years for which the stations have been in operation. The principal application of this flood stage data in the Menomonee River watershed planning program was in developing historic flood stage profiles and calibrating the watershed hydrologic-hydraulic simulation model.

Annual and Monthly Streamflow: Average annual and average monthly streamflow and extremes and variations in those streamflows provide an overview of watershed streamflow characteristics and a framework within which more detailed examinations of daily and instantaneous flows may be considered. Data obtained from the USGS monitoring stations on the Menomonee River for the period from October 1, 1961, through September 30, 1973, facilitate such an analysis.

Mean annual streamflow has ranged from a low in 1963 of 24.0 cfs, or 2.67 inches of runoff over the 123 square mile tributary drainage area, to a high in 1973 of 126 cfs, or 13.93 inches of runoff. The average annual streamflow derived from the 12 year period of record is 74.2 cfs, or 8.19 inches of runoff. While the average annual runoff expressed in inches is reasonably representative of the entire 137 square mile watershed, the average annual runoff expressed in cubic feet per second is not representative of the entire watershed since the USGS gaging station at Wauwatosa monitors flow from a 123 square mile drainage area, or 89.8 percent of the total watershed area. If the 74.2 cfs average annual gaging station discharge is adjusted by multiplying it by ratio of watershed area to area tributary to the gaging station, an average watershed discharge of 82.5 cfs results.

Average monthly watershed runoff is shown in cubic feet per second and in inches as well as maximum and minimum monthly flows in Figure 23. Prolonged periods of high streamflow occur principally in March and April with these months exhibiting average runoff quantities of 1.76 and 1.59 inches, respectively, the sum of which accounts for almost half of the average annual runoff. The minimum monthly runoff generally occurs during the six month period of August through January when monthly runoffs have been less than 0.50 inches for each month except for September which has a somewhat higher average monthly runoff of 0.72 inches.

An examination of the maximum and minimum monthly runoff values shown in Figure 23 indicates that the months of March, April, and September have experienced the largest absolute deviations from the average. These deviations are due to the tendency, in the period of record, for floods to occur during these three months. The largest recorded monthly flow of the Menomonee River was 416 cfs, or 3.90 inches of runoff, in March 1962; the minimum recorded monthly flow was 4.5 cfs, or 0.04 inches of runoff, in January and February of 1963. Monthly flows have, therefore, ranged from a low of about 7 percent of the average annual flow of 74.2 cfs to a high of almost six times that flow.

Flow Duration Analysis: A flow duration curve is defined as a cumulative frequency curve that indicates the percentage of time that specified discharges may be expected to be equaled or exceeded. Figure 24 is a flow duration curve based on daily streamflow measurements as made at the USGS gage on the Menomonee River at Wauwatosa for the 12 water years from 1962 to 1973—the only watershed gaging station that provides sufficient data for construction of a flow duration curve. The daily flows on which the Menomonee River flow duration relationship is based range from a low of 2.8 cfs on January 18, 1974, to a high of 2,870 cfs on July 18, 1964. Since the flow duration curve is based on all daily flows in the period of record, it is an effective means of definitively presenting streamflow characteristics.

Flow duration curves are most frequently used as an aid in forecasting the availability of specified rates of flow. For example, the Menomonee River flow duration curve indicates that a daily flow of 10 cfs has been, and may be expected to be, exceeded 85 percent of the time; whereas much higher daily discharges of 100 cfs and 1,000 cfs have been, and may be expected to be, exceeded only 17 percent and 0.8 percent of the time, respectively.

While the flow duration curve of Figure 24 adequately represents the proportion of days within a year during which a specified daily discharge may be equaled or exceeded, it does not explicitly yield similar information for months within a year. A graphical representation providing daily flow duration information on a monthly basis, as opposed to an annual basis, is shown on Figure 25. This figure indicates, for example, that the Menomonee River discharge at Wauwatosa has exceeded, and may be expected to exceed, 10 cfs on 98 percent of the days in March whereas much higher flows of 100 cfs and 500 cfs have been exceeded, and may be expected to be exceeded on 50 percent and 9 percent, respectively, of the March days.

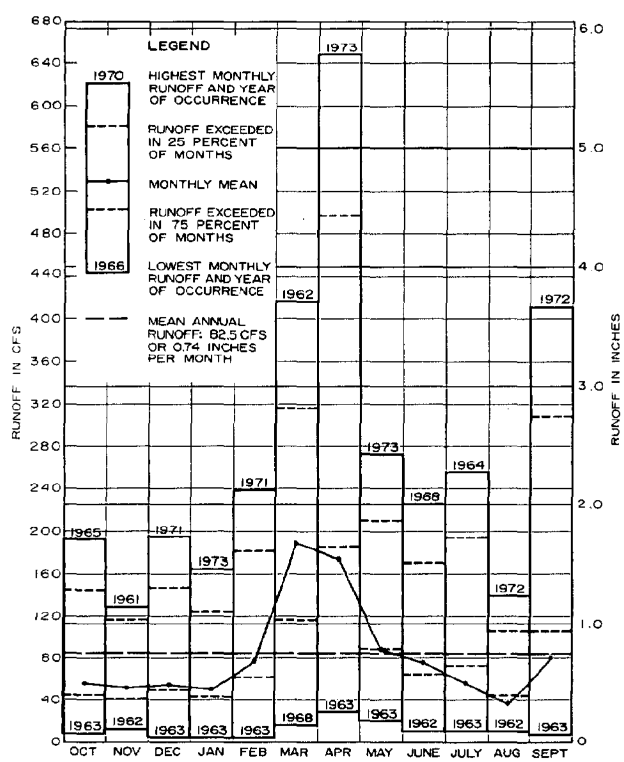
Flow duration information presented in Figure 25 also illustrates the temporal variation of Menomonee River streamflow during the water-year. For example, whereas a streamflow of 100 cfs may be expected to be reached or exceeded on nearly half of the days in March and April, that same flow will be reached or exceeded on less than about 20 percent of the days in the other 10 months of the water-year.

Annual Instantaneous and Daily Peak Discharges: Three of the four USGS gaging stations in the watershed—the Menomonee River gage in Wauwatosa, the Little Menomonee River gage in Mequon, and the Honey Creek gage in Milwaukee—provide data on instantaneous peak discharges for each of the years in the available periods of record. In addition, daily peak discharges have been recorded and identified for the Menomonee River gaging station.

Menomonee River: Instantaneous peak discharges and daily peak discharges for the Menomonee River at Wauwatosa are presented in Table 26 for the 12 water-years

Figure 23

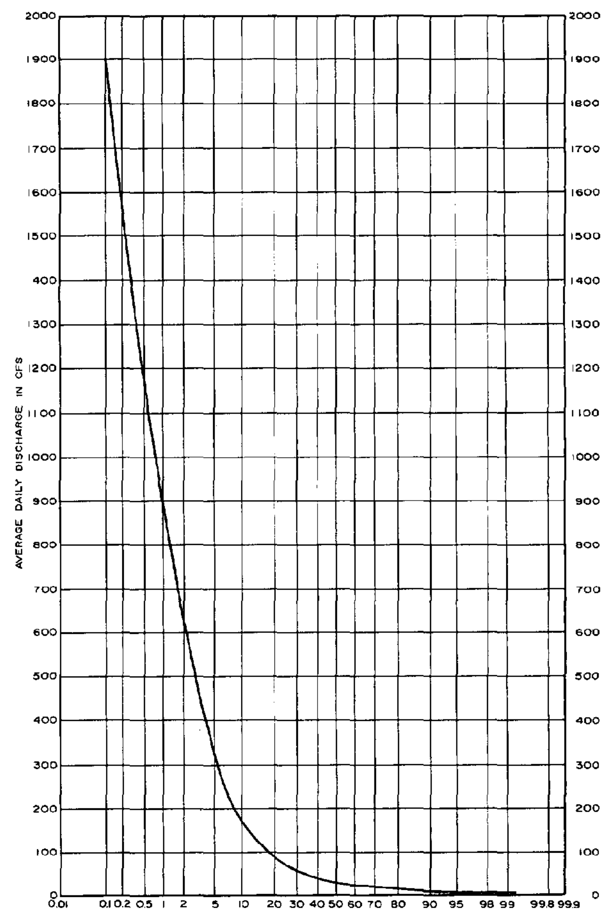
MONTHLY RUNOFF FOR THE MENOMONEE RIVER AT WAUWATOSA: WATER-YEARS 1962-1973 (U. S. GEOLOGICAL SURVEY GAGE NO. 04087120)



Source: U. S. Geological Survey (Gage No. 04087120) and SEWRPC.

Figure 24

FLOW DURATION CURVE FOR THE MENOMONEE RIVER AT WAUWATOSA: WATER-YEARS 1962-1973 (U. S. GEOLOGICAL SURVEY GAGE NO. 04087120)



Source: U. S. Geological Survey (Gage No. 04087120) and SEWRPC.

of available record from 1962 through 1973. Figure 26 is a graphical presentation of the instantaneous peak discharge of the Menomonee River by date of occurrence and is intended to show the seasonal distribution of the instantaneous annual peak discharges. Instantaneous annual peak discharges have ranged from 900 cfs on March 16, 1963 to 13,500 cfs on April 21, 1973. The mean of the 12 annual instantaneous peak discharges of record is 3,910 cfs, whereas the mean of the 12 annual daily peak discharges is 1,953 cfs.

Temperature data, snow cover information and concurrent precipitation values were used to determine, as indicated in Table 26, the probable causative meteorological event for each of the 12 annual instantaneous peak discharges and the 12 annual daily peak discharges that have been recorded on the Menomonee River at Wauwatosa. Seven of the annual instantaneous peak discharges—over half—have resulted from rainfall events, two from snowmelt events and three from combination rainfall-snowmelt events. A similar preponderance of rainfall events exists as the cause of the annual daily peak discharges.

With two exceptions, the set of events causing the annual instantaneous peak discharges is the same as the set of events containing the annual peak discharges. The two exceptions are the August 20, 1968, flood event which had one of the 12 largest instantaneous peak discharges of record, although not one of the 12 largest daily peak discharges, and the June 26, 1968, flood event which had one of the 12 largest daily peak discharges of record, although not one of the 12 largest instantaneous peak discharges of record.

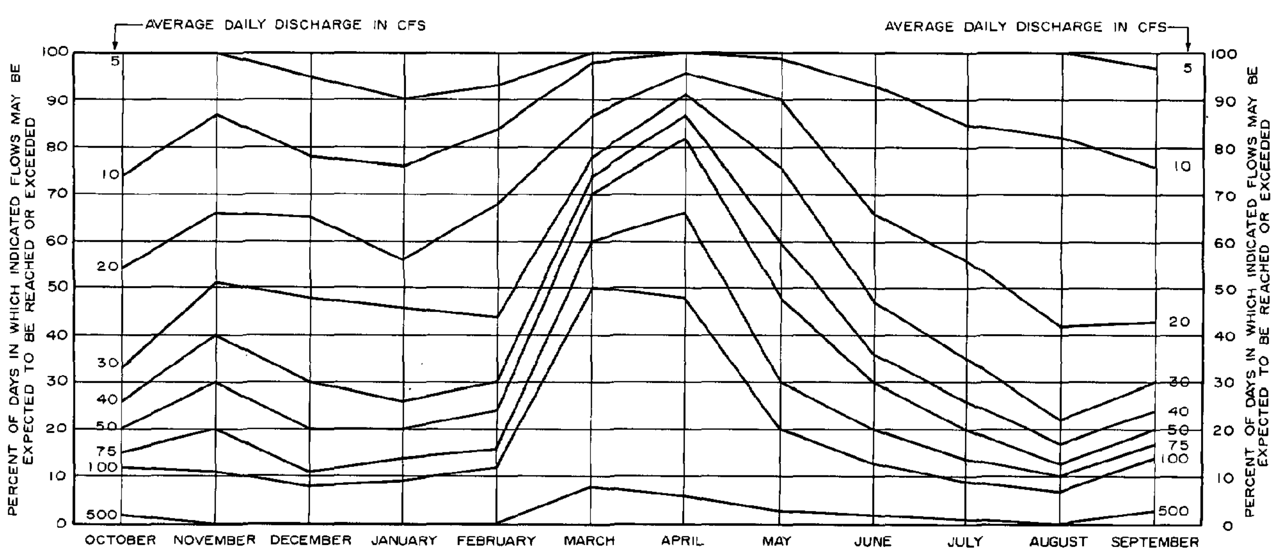
The annual instantaneous peak discharges and annual daily peak discharges appearing in Table 26 are listed and ranked in order of decreasing magnitude. A close correlation does not exist between the rank of an event in the instantaneous discharge portion of the table and the rank of the same event in the daily discharge portion of the table, primarily because the largest annual instantaneous peak discharges in the historic record are the result of rainfall events, whereas the largest annual daily peak discharges do not exhibit such a tendency. For example, the five largest annual instantaneous peak discharges recorded on the Menomonee River at Wauwatosa were caused by rainfall events as opposed to rainfall-snowmelt or snowmelt events.

Estimates of the direct runoff, that is, the volume of flow in excess of groundwater or base flow that passed the gaging station as a result of a rainfall-snowmelt event, are also included in Table 26 for the flood events associated with the daily peak discharges. These runoff volumes have a mean value of 1.73 inches and range from a low of 0.72 inches for the June 1967 flood to a high of 3.06 inches for the April 1973 flood. The rank of the direct runoff values does not correlate with the rank of either the annual daily peak discharges or the annual instantaneous peak discharges. Runoff volume appears to be a function of the soil type and conditions and of the type of event—rainfall, snowmelt, rainfall-snowmelt—that caused the flood, with snowmelt and snowmelt-rainfall events tending to produce the largest volume of direct runoff.

Little Menomonee River: Annual instantaneous peak discharges for the Little Menomonee River in the City of

Figure 25

FLOW DURATION RELATIONSHIPS BY MONTH FOR THE MENOMONEE RIVER AT WAUWATOSA: WATER-YEARS 1962-1973 (U. S. GEOLOGICAL SURVEY GAGE NO. 04087120)



Source: U. S. Geological Survey (Gage No. 04087120) and SEWRPC.

Table 26

ANNUAL INSTANTANEOUS AND DAILY PEAK DISCHARGES OF THE MENOMONEE RIVER AT WAUWATOSA: WATER-YEARS 1962-1973

Instantaneous Discharge									
		Date					Causative Event		
Discharge (cfs)	Rank	Day	Month	Water Year	Calendar Year	Recurrence Interval[a] (Years)	Rainfall	Snowmelt	Rainfall and Snowmelt
13,500	1	21	April	1973	1973	28.60	x		
6,610	2	18	September	1972	1972	6.90	x		
6,010	3	18	July	1964	1964	5.88	x		
4,660	4	20	August	1968	1968	3.92	x		
3,050	5	25	June	1969	1969	2.22	x		
2,520	6	9	February	1966	1966	1.82			x
2,190	7	5	March	1965	1965	1.59			x
2,180	8	15	March	1971	1971	1.58			x
2,050	9	2	June	1970	1970	1.50	x		
1,700	10	10	June	1967	1967	1.32	x		
1,560	11	25	March	1962	1962	1.25		x	
900	12	16	March	1963	1963	1.03		x	

Daily Discharge										
		Date						Causative Event		
Discharge (cfs)	Rank	Day	Month	Water Year	Calendar Year	Corresponding Direct Runoff of Flood Event (Inches Over the Watershed)	Rank of Direct Runoff	Rainfall	Snowmelt	Rainfall and Snowmelt
6,380	1	21	April	1973	1973	3.06	1	x		
2,870	2	18	July	1964	1964	2.16	3	x		
2,520	3	18	September	1972	1972	1.53	7	x		
2,100	4	9	February	1966	1966	1.59	6			x
1,610	5	5	March	1965	1965	2.16	4			x
1,550	6	15	March	1971	1971	1.32	9			x
1,430	7	2	June	1970	1970	0.79	11	x		
1,420	8	25	March	1962	1962	3.04	2		x	
1,180	9	26	June	1969	1969	1.51	8	x		
1,100	10	26	June	1968	1968	1.74	5	x		
781	11	10	June	1967	1967	0.72	12	x		
500	12	16	March	1963	1963	1.16	10		x	

[a] *Recurrence intervals based on Log-Pearson Type III analysis.*

Source: U. S. Geological Survey (Gage No. 04087120) and SEWRPC.

Mequon are set forth in Table 27 for the 16 water-years of record through 1973. These instantaneous annual peak discharges have a mean value of 193 cfs and range from a low value of 63 cfs in March 1958[4] to a high of 360 cfs on April 21, 1973. The 16 annual instantaneous peak discharges are not distributed uniformly throughout the year in that seven have occurred in the spring and five in the summer, while only four have occurred in the fall and winter seasons.

The flood events associated with annual instantaneous peak discharges on the Little Menomonee River are not generally the same events responsible for the annual instantaneous peak discharges on the Menomonee River at Wauwatosa. Data for both stations are available for the 12 water-years from 1962 through 1973 and a comparison of instantaneous peak discharges at the Little Menomonee River and Menomonee River gaging stations for each of these years indicates that the same events were responsible for the peak discharges in only 4 of the 12 years.

Honey Creek: Annual instantaneous peak discharges for Honey Creek in the City of Milwaukee are set forth in Table 27 for the 15 water-years of record from 1959 through 1973. These instantaneous annual peak discharges have a mean value of 276 cfs and range from

[4] *Day unknown.*

a low of 115 cfs on August 12, 1963, to a high of 680 cfs on September 18, 1972. The 15 annual instantaneous peak discharges are not distributed uniformly throughout the year; nine occurred in summer, while only three occurred in spring, two in winter, and one in fall.

The flood events associated with annual instantaneous peak discharges on Honey Creek are not generally the same events that caused the annual instantaneous peak discharges of the Menomonee River as recorded at Wauwatosa. Comparison of peak discharge data obtained for both Honey Creek and the Menomonee River for the 12 water-years of record from 1962 through 1973 reveals that the same events were responsible for the annual instantaneous peak discharges in only 5 of the 12 years. The absence of a strong correlation between the occurrence of the above annual instantaneous peak discharges on the Menomonee River, the Little Menomonee River, and Honey Creek probably reflects spatially different meteorologic conditions such as the occurrence of highly localized, short duration, intense rainfall events.

Seasonal Distribution of Peak Flows: As shown in Tables 26 and 27, and in Figure 26, all the recorded instantaneous annual peak discharges for the Menomonee River, the Little Menomonee River, and Honey Creek generally occur during the three seasons of late winter, spring and summer and, although not uniformly distributed among three seasons for all three locations, are definitely not concentrated within any given season. In the case of the Menomonee River at Wauwatosa, 4 of the 12 annual recorded annual instantaneous peaks occur in the winter, four in spring, and four in summer.

This distribution of annual instantaneous peak discharges in the Menomonee River watershed is in marked contrast to the seasonal distribution pattern observed in completed Commission studies on the 197 square mile Root River watershed, the 939 square mile Fox River watershed, and the 694 square mile Milwaukee River watershed. In these watersheds, each of which is significantly larger than the Menomonee River watershed, the instantaneous peak discharges at or near the watershed outlets tended to be concentrated in the late winter-early spring portion of the year. For example, of the 54 annual instantaneous peak discharges that occurred on the Milwaukee River in the 1915-1968 period, 32 or 59 percent occurred during March or April as did five of the six largest discharges.

The difference in the seasonal characteristics of peak flood events in the Menomonee River watershed relative to the Root, Fox, and Milwaukee River watersheds is due primarily to the size difference and the resulting

Table 27

ANNUAL INSTANTANEOUS PEAK DISCHARGES FOR THE LITTLE MENOMONEE RIVER AND HONEY CREEK: WATER-YEARS 1958-1973

Water Year	Little Menomonee River (USGS Gage No. 4-0870.5)					Honey Creek[a] (USGS Gage No. 4-0871)				
	Discharge (cfs)	Rank	Date			Discharge (cfs)	Rank	Date		
			Day	Month	Calendar Year			Day	Month	Calendar Year
1958	63	16	N/A[b]	March	1958	--	--	--	--	--
1959	200	7	2	April	1959	240	7	18	July	1959
1960	305	3	19	September	1960	285	5	2	August	1960
1961	105	13	31	October	1960	230	8	22	September	1961
1962	150	11	26	March	1962	140	14	24	August	1962
1963	123	12	24	March	1963	115	15	12	August	1963
1964	340	2	18	July	1964	259	6	18	July	1964
1965	225	5	9	September	1965	185	12	8	August	1965
1966	300	4	21	October	1965	190	11	9	February	1966
1967	70	15	11	June	1967	210	9	11	June	1967
1968	100	14	28	June	1968	210	10	24	September	1968
1969	215	6	26	June	1969	290	4	29	June	1969
1970	160	10	13	May	1970	310	3	2	June	1970
1971	200	8	28	March	1971	150	13	19	February	1971
1972	165	9	15	December	1971	680	1	18	September	1972
1973	360	1	21	April	1973	640	2	21	April	1973

[a]Channel improvements on Honey Creek upstream of USGS Gage No. 4-0871 were completed in 1973.

[b]Note: N/A indicates date not available.

Source: U. S. Geological Survey and SEWRPC.

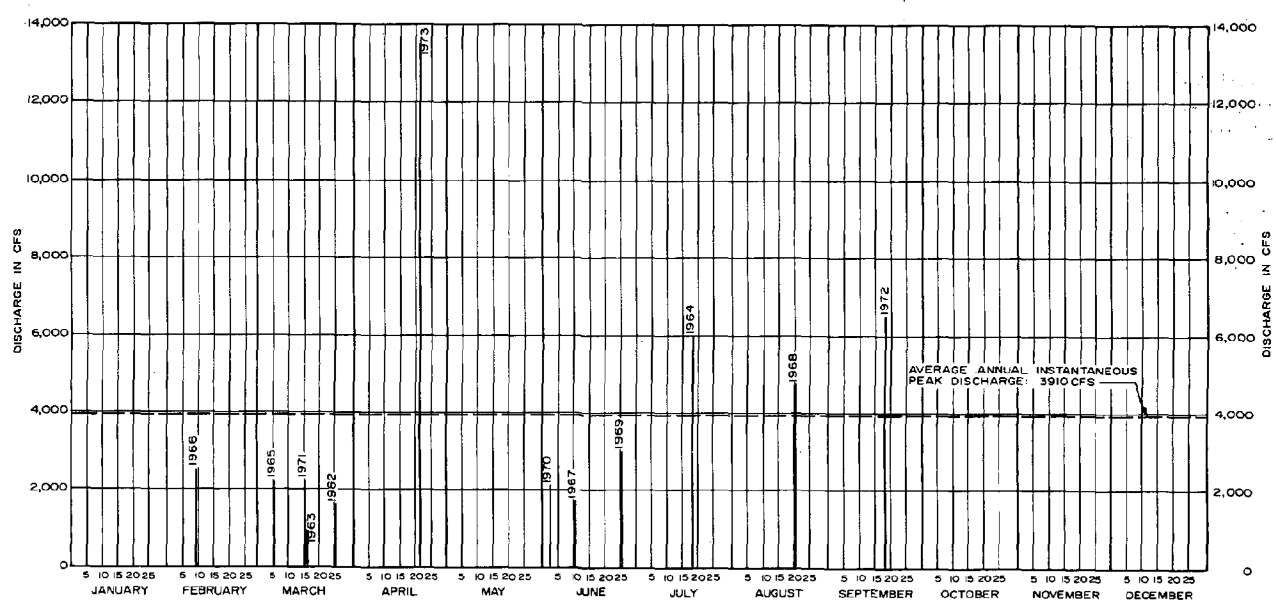
relative importance of rainfall versus rainfall-snowmelt induced flood events. Although major rainfall events commonly occur in spring, summer, and fall, they have not been the sole causative factor for major floods in the lower reaches of the Root, Fox, and Milwaukee River watersheds. This is because major rainfall events do not occur with sufficient intensity and duration over large enough areas of the Region to produce flood peaks of similar magnitude to those that occur as a result of snowmelt or a combination snowmelt-rainfall condition on these large watersheds. Unlike rainfall, snowmelt does occur over large geographic areas since it is primarily a function of air temperature and snow cover distribution.

As smaller and smaller watersheds or subwatersheds are considered, rainfall events assume increased importance as the causative factor for flood events. The Menomonee River watershed is sufficiently small so the rainfall is the primary cause of major flood events for not only its subwatersheds but also for the entire watershed. As discussed above, rainfall alone has been responsible for the occurrence of 7 of the 12 annual instantaneous peak discharges of the Menomonee River at Wauwatosa during the period 1962-1973. When rainfall is the dominant cause of flood events, as it is for example in the entire Menomonee River watershed, annual instantaneous peak discharges tend to be more uniformly distributed throughout the year since rainfall-producing thunderstorms do occur anytime during the spring, summer, and fall seasons. In summary, then, most major flood events in the Menomonee River watershed have been and may be expected to continue to be the result of rainfall activity and, therefore, have occurred and will continue to occur with little warning anytime during the late winter, spring, and summer of the year.

High Flow Discharge-Frequency Relationships: The most important hydrologic characteristics of floods are the probabilities or frequencies of occurrence, the peak rate of discharge, the volume of runoff, and the duration and timing of the event. "Probability" or "frequency" is defined as the chance of occurrence, in any year, of a flood equaling or exceeding a specified magnitude. Probability may be expressed as a decimal, a fraction, or a percentage. "Recurrence interval" is defined as the average time interval between floods of a given magnitude and is equal to the reciprocal of the probability. For example, a flood that would be equaled or exceeded on the average of once in 100 years would have a recurrence interval of 100 years and a 0.01 probability or 1 percent of chance of occurring or being exceeded in any year.

Figure 26

SEASONAL DISTRIBUTION OF ANNUAL INSTANTANEOUS PEAK DISCHARGES OF THE MENOMONEE RIVER AT WAUWATOSA: WATER-YEARS 1962-1973 (U. S. GEOLOGICAL SURVEY GAGE NO. 04087120)



Source: U. S. Geological Survey (Gage No. 04087120) and SEWRPC.

A long and continuous record of river discharge is the best basis for determination of flood discharge frequency relationships. Discharge records for the Menomonee River at Wauwatosa encompass only 12 water-years of record and are not, therefore, of sufficient length to provide a good basis for discharge-frequency analyses for more infrequent flood events. The length of the available streamflow record for the Menomonee River was, however, judged adequate for the development of reasonably reliable discharge-frequency relationships for discharge up to and including that of 10-year recurrence interval. The effect of the length of streamflow record on the accuracy of discharge-frequency relationships developed from that record has been investigated. A study[5] of all and of portions of the 68 years of discharge records for the Minnesota River, for example, assumed that accurate 10 through 100 year recurrence interval discharges would be obtained if all 68 years of record were used in a log-Pearson Type III discharge-frequency analysis and then the error that resulted from using only portions of the available record was evaluated. When various consecutive 10-year portions of the 68 years of available record were used, the error in determining the 10-year recurrence interval flood discharge varied from minus 58 percent to plus 68 percent, whereas the errors in determining the 100-year recurrence interval flood discharge were larger and ranged from minus 67 percent to plus 211 percent. For a given recurrence interval, the range of error in the computed discharge diminished as longer segments of the available record were used. A U. S. Geological Survey study concluded that 48 years of record would be needed to estimate the 100-year recurrence interval flood within 25 percent and 115 years to obtain an estimate within 10 percent.[6]

Short periods of record tend to result in overestimation rather than underestimation of peak flood discharges for specified recurrence intervals. For example, results of investigations conducted at Stanford University indicate that the probability of overestimating 10 through 100-year recurrence interval discharges is in excess of 80 percent if only 10 years of data are available and that the probability of overestimating drops to 69 percent if 50 years of data are used and 62 percent if 100 years are used.[7] Over 250 years of streamflow data would be required to develop a stable discharge-frequency curve, that is, one that is just as equally likely to overestimate or underestimate discharge values for specified recurrence intervals.

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[5] *Victorov, P., "Effect of Period of Record on Flood Prediction," "Journal of the Hydraulics Division, ASCE, Volume 97, No. HY 11, November 1971, pp. 1853-1866.*

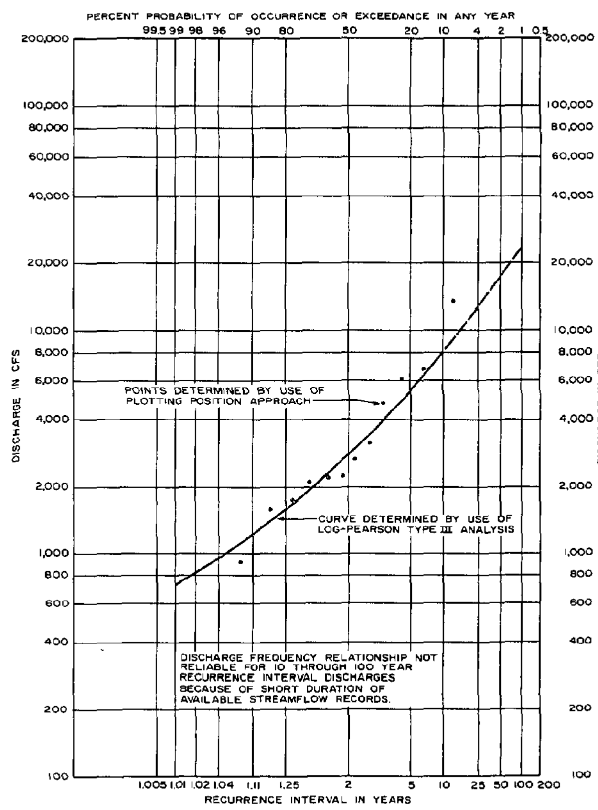
[6] *Benson, M., "Characteristics of Frequency Curves Based on a Theoretical 1,000 Year Record," U. S. Geological Survey, Water Supply Paper 1543-A, pp. 51-77, 1960.*

[7] *Ott, R. F., "Streamflow Frequency Using Stochastically Generated Hourly Rainfall," Technical Report No. 151, Department of Civil Engineering, Stanford University, December 1971.*

Annual instantaneous peak discharges of the Menomonee River as recorded at the USGS wire weight gage in Wauwatosa were used to determine 1, 2, 5, and 10 year recurrence interval discharges recognizing, as discussed above, that the discharges would not be reliable for recurrence intervals beyond about 10 years. Statistical analyses required to compute the discharges corresponding to the specified recurrence intervals were conducted using the log-Pearson Type III method of analysis. That method was used because—as discussed in Chapter II, Volume 2, "Watershed Development Objectives, Principles and Standards"—it is recommended by the United States Water Resources Council and is specified for floodplain regulatory purposes by the Wisconsin Department of Natural Resources even though it is not superior to other available methods, especially for records of relatively short duration. One, 2, 5, and 10-year recurrence interval instantaneous peak discharges values of 680, 2,540, 4,255, and 5,625 cfs, respectively, were obtained from the log-Pearson Type III analysis. A graphical representation of the resulting discharge-frequency relationship is shown in Figure 27.

Figure 27

DISCHARGE-FREQUENCY RELATIONSHIP OF THE MENOMONEE RIVER AT WAUWATOSA WATER-YEARS 1962-1973 (U. S. GEOLOGICAL SURVEY GAGE NO. 04087120)



Source: U. S. Geological Survey (Gage No. 04087120) and SEWRPC.

Discharges corresponding to recurrence intervals up to 100 years are required in the watershed plan preparation and implementation process not only for the Menomonee River at Wauwatosa but for much of the watershed stream system. As described in Chapter VIII, "Water Resource Simulation Model," a digital computer model calibrated against the relatively short historic streamflow record but utilizing available long term (35 year) meteorological data was used to determine discharge-frequency relationships for 10 through 100 year recurrence interval discharges at locations throughout the Menomonee River watershed. The relatively large historic meteorological data base was used, by means of the simulation model, to extend the inadequate, short historic streamflow record of 12 instantaneous annual peak flows to an acceptable number of 35 annual instantaneous peak flows. Discharge-frequency analyses were then conducted on this 35-year series to estimate the 10 through 100-year recurrence interval discharges.

Whereas Figure 27 presents the discharge-frequency relationship for instantaneous peak discharges, Figure 28 shows high flow discharge-frequency relationships applicable to the Menomonee River at Wauwatosa for finite periods of 1 day, 7 days, 30 days, and 120 days. These relationships were developed using the log-Pearson Type III method of statistical analysis and—as was the case with the analysis of annual instantaneous peak discharges—are judged to be reliable for recurrence intervals of up to 10 years.

For a specified discharge, these curves facilitate the probability estimate that a specified streamflow will be maintained for a given period of time during any water year. For example, the probability of maintaining an average flow of 200 cfs or more for a seven-day period in any water-year is about 99 percent, whereas the probability of maintaining that flow for 30 days is a lower 75 percent and for 120 days an even lower 10 percent.

Low Flow Discharge-Frequency Relationships: Figure 29 shows low flow discharge-frequency relationships for the Menomonee River at Wauwatosa for periods of 1 day, 7 days, 30 days, and 120 days. The log-Pearson Type III method of statistical analysis was used to develop these curves, and they are judged to be reliable for recurrence intervals up to 10 years.

Low flow discharge-frequency relationships are useful in the water quality management aspects of comprehensive watershed studies. For example, the low flow condition established by the Wisconsin Department of Natural Resources for evaluating compliance with water use objectives and supporting standards is a streamflow equivalent to the average minimum seven-day flow expected to occur once on the average of every 10 years. The seven day-ten year low flow for the Menomonee River at Wauwatosa is, as obtained from Figure 29, 3.4 cfs. This may be interpreted to mean that once on the average of every 10 years there will be a seven-day period in which the average Menomonee River discharge at Wauwatosa will be 3.4 cfs or less.

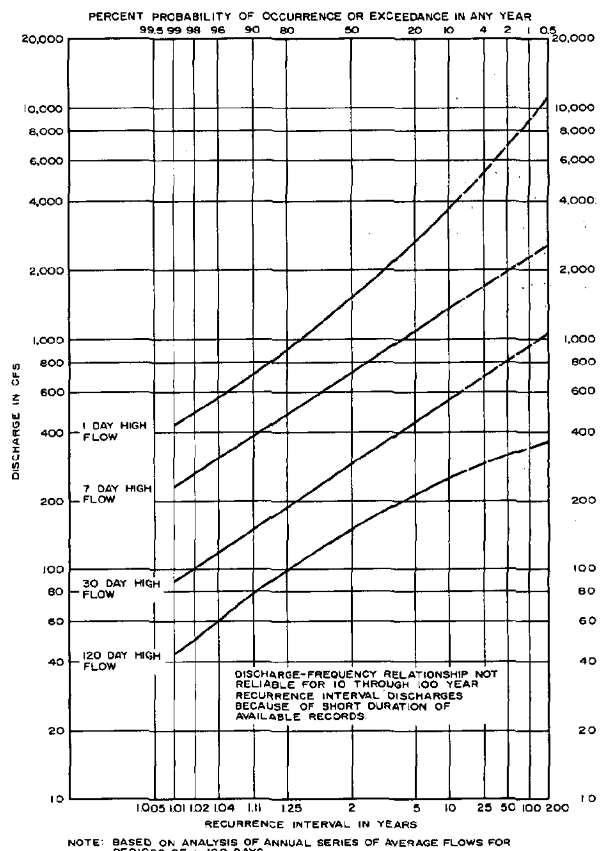
Factors Affecting the Surface Water Phase of the Hydrologic Cycle

A comprehensive evaluation of the surface water hydrology of a watershed must consider the existing physical characteristics of the watershed as an interrelated whole, while identifying the individual effect of each of the component physical characteristics on the unique surface water hydrology of the watershed. The physical characteristics of a watershed which influence the volume and temporal distribution of surface water runoff include all natural characteristics such as soils, topography, and causative meteorological events and man-made features such as the type, intensity, and spatial distribution of land use.

The following discussion of each of these natural and man-made factors affecting the volume and temporal distribution of surface waters entering the stream system of the Menomonee River watershed is based primarily on historic and existing hydrologic data and hydrologic-related information. As described in Chapter VIII,

Figure 28

HIGH FLOW DISCHARGE-FREQUENCY RELATIONSHIPS OF THE MENOMONEE RIVER: WATER-YEARS 1962-1973 (U. S. GEOLOGICAL SURVEY GAGE NO. 04087120)



Source: U. S. Geological Survey (Gage No. 04087120) and SEWRPC.

"Water Resource Simulation Model," digital computer modeling was used to supplement this existing and historic data base by examining the effects of alternative future land uses on the surface water phase of the hydrologic cycle.

While the following discussion concentrates on factors affecting the volume and temporal distribution of surface water entering the Menomonee River watershed stream system, it is important to note that flow stages and velocities in that stream system as well as areas of inundation are largely determined by the hydraulic characteristics of the stream system. The hydraulics of the stream system are described and discussed later in this chapter.

Influence of Soils on Runoff: As noted in Chapter III, "Description of the Watershed," an especially complex pattern of soil types has developed in the Menomonee River watershed as a result of the heterogeneous glacial materials interacting with and being affected by topography, climate, plants, and animals. Watershed soils have been surveyed and mapped, their characteristics—such as texture, structure, color, consistence, reaction, slope, and position—have been identified and their properties—such as infiltration capacity, permeability, moisture capacity, and erodibility—have been determined. Most importantly, the soil survey data have been interpreted for engineering, agricultural, resource conservation, and urban and rural planning purposes.

As an integral part of these soil surveys and interpretations, the soils of the Menomonee River watershed have been classified into four hydrologic soil groups, designated A, B, C, and D, based upon those soil properties affecting runoff. In terms of runoff characteristics, these four soil groups range from Group A soils which exhibit very little runoff because of high infiltration capacity, high permeability and good internal drainage, to Group D soils which generate large amounts of runoff because of low infiltration capacity, low permeability, and poor internal drainage. The spatial distribution of the four hydrologic soil groups within the Menomonee River watershed is shown on Map 30, and the relative dominance of the four hydrologic soil groups is summarized in Figure 30.

Hydrologic Soil Group C is dominant in the watershed in that soils in this group cover about 67 square miles, or about 60 percent of the 115 square mile portion of the watershed for which detailed soils data are available. Soil Groups A, B, and D cover 0.01, about 14 and about 17 percent of that 115 square mile area respectively. Thus, for the watershed as a whole, the soils may be expected to produce relatively large amounts of runoff for a given rainfall or rainfall-snowmelt event.

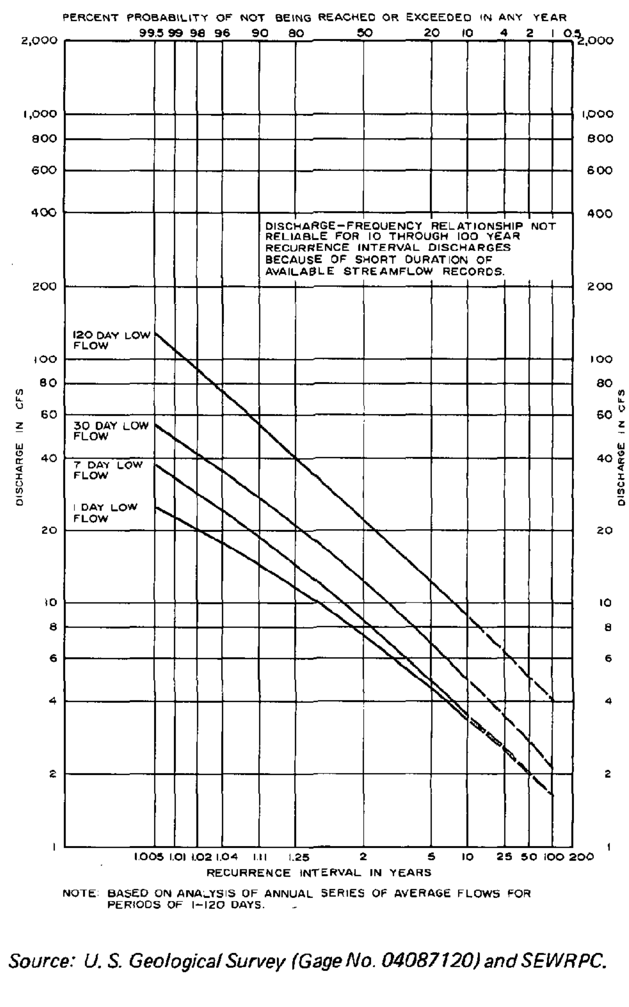
The impact of soil type on runoff characteristics is illustrated by the fact that if 4.0 inches of rainfall fall on pasture land underlain by soils in Hydrologic Soil Group A under average antecedent soil moisture conditions, only about 0.3 inches could be expected to run off directly to the watershed stream system; whereas, if the pasture were underlain by soils in Hydrologic Soil Group D—which lies at the other end of the soil spectrum with respect to runoff potential—about 2.5 inches or eight times as much could be expected to appear as direct runoff. Under similar situations, Hydrologic Soil Groups B and D could be expected to generate 1.3 inches and 2.0 inches, respectively, of direct runoff.[8]

Hydrologic soil group data, therefore, constitute an important consideration in the preparation of input for the computer model used to simulate the hydrologic characteristics of the Menomonee River watershed. Because of the high runoff potential of the underlying soils and the extensive urbanization which has already

[8] *U. S. Department of Agriculture, Soil Conservation Service, National Engineering Handbook, Section 4-Hydrology, 1964.*

Figure 29

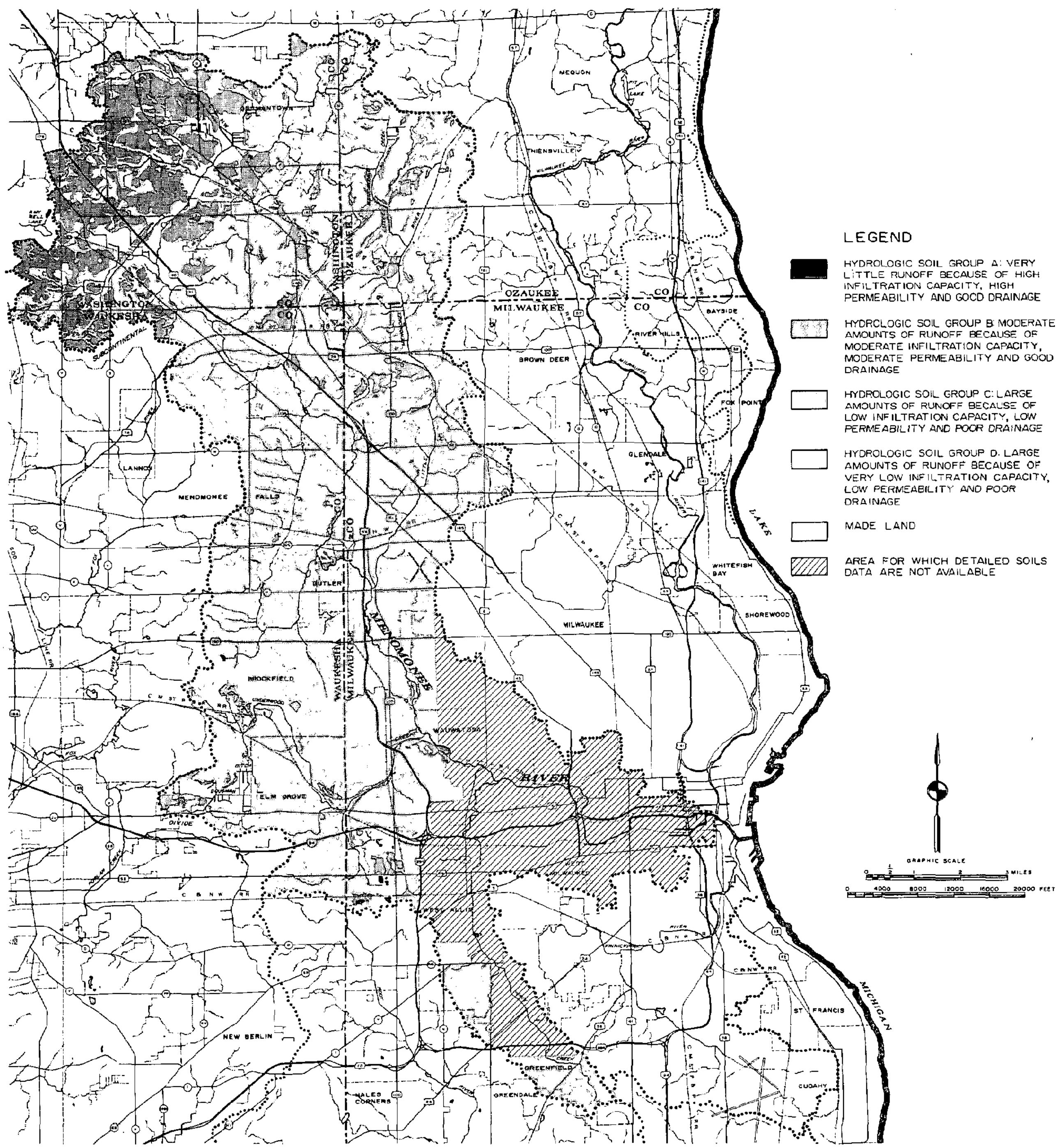
LOW FLOW DISCHARGE-FREQUENCY RELATIONSHIPS OF THE MENOMONEE RIVER: WATER-YEARS 1962-1973 (U. S. GEOLOGICAL SURVEY GAGE NO. 04087120)



Source: U. S. Geological Survey (Gage No. 04087120) and SEWRPC.

Map 30

HYDROLOGIC SOIL GROUPS IN THE MENOMONEE RIVER WATERSHED



The spatial distribution of the four hydrologic soil groups within the Menomonee River watershed is shown above. Hydrologic Soil Group C is dominant in the watershed with soil groups A, B, and D also represented but in smaller proportions. The preponderance of soils that produce relatively large volumes of runoff suggests that the rate and amount of runoff from the watershed may not be as sensitive to urbanization as are some of the other watersheds in southeastern Wisconsin.

Source: SEWRPC.

occurred in the watershed—about 54 percent of the watershed was in urban land use as of 1970—the Menomonee River watershed may be expected to exhibit large runoff volumes and discharges relative to other watersheds of similar geographic location and size within the Region. The preponderance of soils that produce relatively large volumes of runoff suggests that the rate and amount of runoff from the watershed may not be as sensitive to urbanization of lands outside of the floodlands as might otherwise be the case.

Influence of Surface Water Storage Areas on Runoff: Natural surface water storage areas in a watershed serve to modify runoff from rainfall or rainfall-snowmelt events primarily by flattening the hydrograph—that is, by decreasing peak discharges and lengthening the duration of direct runoff—and by diminishing the volume of direct runoff as a result of increased infiltration. Natural surface water storage areas can generally be divided into the following three groups: lakes, wetlands, and floodland areas.

As noted in Chapter III, "Description of the Watershed," there are no major lakes—that is, lakes of 50 acres or more in surface area—in the Menomonee River watershed. Furthermore, primarily because of the extensive urbanization that has already occurred in the watershed, wetland areas have been reduced to only 2.8 percent of the watershed area, a low percentage compared to other, more rural, watersheds in the Region. Therefore, with respect to the first two categories of surface water storage areas, there is little potential for modification of direct runoff.

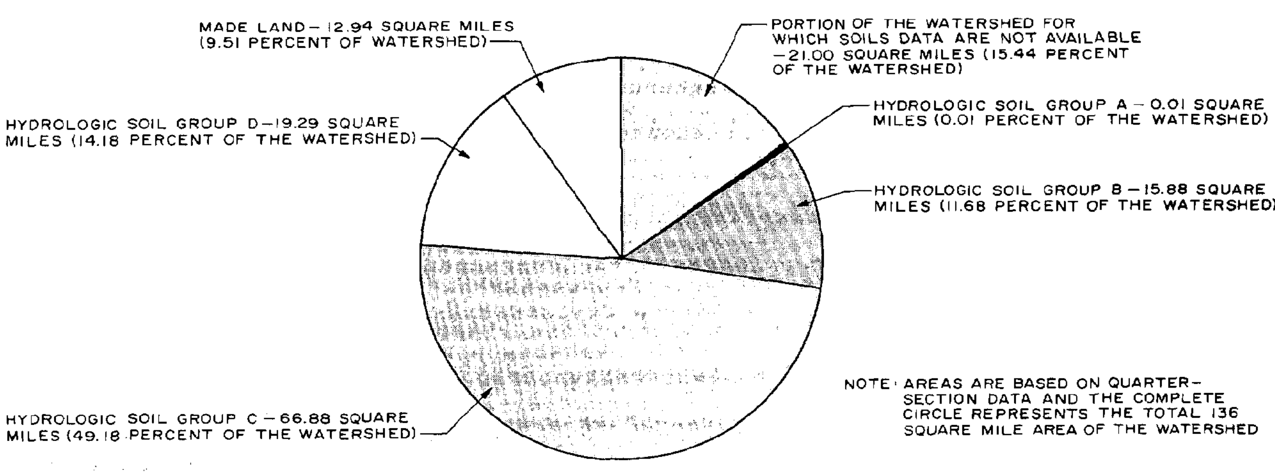
The third type of surface water storage area consists of the floodlands generally associated with streams and water courses. Because of the absence of major lakes and because of the small amount of remaining wetland areas in the Menomonee River watershed, the remaining floodlands constitute the only natural surface water storage areas in the watershed with potential for reducing peak rates of runoff. Floodlands are an integral part of the stream system of the watershed and, as such, are regularly inundated by flood waters. During inundation the floodlands, in effect, store and retard direct runoff, thereby decreasing downstream flood discharges and accompanying stages.

Urban development in a watershed should be designed so as not to adversely diminish the surface water storage areas and the attendant peak flood flow reduction potential of the floodlands. These protective conditions are particularly critical in the Menomonee River watershed inasmuch as floodlands constitute the only significant remaining surface water storage areas in the watershed. The potential adverse downstream effect of floodland fill is illustrated by the findings of a study of the 100-square mile relatively flat area tributary to the North Branch of the Chicago River located in extreme northeastern Illinois.[9] Based on hydrologic-hydraulic simulation, it was concluded that floodplain fill up to the channel limit would alter the watershed hydrologic-hydraulic regime to the extent that 100-year recurrence interval flood discharges at the watershed outlet could be expected to double or triple. Similar simulation studies applied specifically to the Menomonee River watershed are described in Chapter VIII of this report, "Water Resource Simulation Model."

[9] *Hydrocomp International, "Simulation of Discharge and Stage Frequency for Floodplain Mapping in the North Branch of the Chicago River," February 1971.*

Figure 30

HYDROLOGIC SOIL GROUPS IN THE MENOMONEE RIVER WATERSHED



Source: SEWRPC.

Influence of Meteorological Events on Runoff: As discussed earlier in this chapter, major flood events in the Menomonee River watershed tend to be distributed throughout the late winter, spring, and summer seasons and are the result of rainfall events and of combination rainfall-snowmelt events. Hydrographs produced by rainfall events are distinctly different from hydrographs resulting from rainfall-snowmelt events, with the former exhibiting rapid rise and fall in discharge and a short time base, while the latter are characterized by more moderate rates of rise and fall and larger times bases.

The characteristic difference between rainfall and rainfall-snowmelt hydrographs is illustrated in Figure 31 using two hydrographs, recorded on the Menomonee River at Wauwatosa, each having a direct runoff of 2.16 inches. One hydrograph is for the rainfall event that occurred in July 1964 while the other hydrograph resulted from late February-early March 1965 rainfall-snowmelt. Although the runoff volumes are equal, the hydrograph shapes and the peak rates of discharge differ markedly. The rainfall event hydrograph has a peak daily discharge of 2,870 cfs, which is 78 percent larger than the peak daily discharge of 1,610 cfs for the rainfall-snowmelt hydrograph. Instantaneous peak discharges on the peak day for the two hydrographs are 6,010 cfs for the rainfall event, which is 174 percent larger than the 2,190 cfs recorded for the rainfall-snowmelt event. The rising limb of the rainfall event hydrograph encompasses a period of one day, whereas six days passed from the time when the rainfall-snowmelt hydrograph began to develop until the day when the peak flow was achieved. The rainfall event hydrograph suggests that when rainfall is the causative event, there is in effect little time to give warning of, or to protect against, rising flood waters in the Menomonee River watershed.

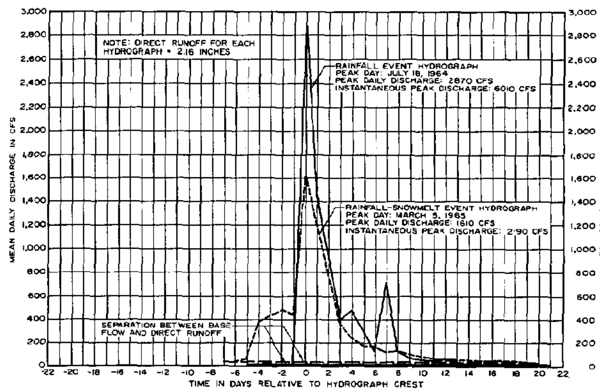
Figure 32 shows two Menomonee River hydrographs for flood events having approximately equal peak daily discharges. The first hydrograph is for the rainfall flood event that occurred in June 1970 and the second hydrograph, recorded in late March-early April 1962, was generated by snowmelt. The rainfall event hydrograph has a peak daily discharge of 1,430 cfs, while the snowmelt event hydrograph developed an approximately equal peak daily discharge of 1,420 cfs. The instantaneous peak discharge of the former was 2,050 cfs, while that of the latter was 1,560 cfs. Although the daily peak discharges are approximately the same, the shapes of the hydrographs and the attendant direct runoff volumes differ markedly. The direct runoff volume for the rainfall event hydrograph is equivalent to 0.79 inches over the watershed, or only 26 percent of the 3.04 inches of direct runoff that occurred as a result of the snowmelt event. While the crest of the rainfall event hydrograph occurred two days after the initiation of direct runoff, the time to peak for the snowmelt event hydrograph was 10 days. The base of the snowmelt hydrograph is 25 days—about two and one-half times the base of the rainfall hydrograph.

In summary, then, the nature of direct runoff flood hydrographs from the Menomonee River watershed is influenced markedly by the type of meteorological event causing the flood event. For approximately equal volumes of direct runoff, rainfall events generate much larger daily and instantaneous peak flows than do snowmelt or combination rainfall-snowmelt events.

Influence of Land Use on Runoff: Urbanization is the conversion of lands from rural to urban use, not only in the floodlands of the watershed but on lands outside the

Figure 31

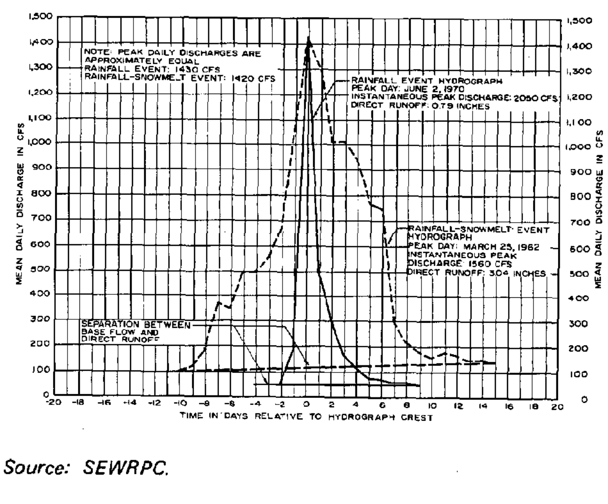
HYDROGRAPHS OF RAINFALL AND RAINFALL-SNOWMELT EVENTS WITH EQUAL VOLUMES OF DIRECT RUNOFF FOR THE MENOMONEE RIVER AT WAUWATOSA: SELECTED DATES, 1964, 1965



Source: SEWRPC.

Figure 32

HYDROGRAPHS OF RAINFALL AND SNOWMELT EVENTS WITH APPROXIMATELY EQUAL PEAK DAILY DISCHARGES FOR THE MENOMONEE RIVER AT WAUWATOSA SELECTED DATES, 1962, 1970



Source: SEWRPC.

floodlands. Urbanization can increase downstream flood discharges and stages in the absence of compensatory detention storage or other similar structural flood control measures. Increased discharges result from the more extensive areas covered by impervious surfaces and the shortened times of concentration, or runoff, which follow the conversion of land from rural to urban use. These effects will, of course, be added to the increase in downstream discharges and stages that may result, as discussed above, from loss of riverine area conveyance and storage capacity as a result of filling and development within the floodlands of the watershed.

The rainfall-runoff relationship is influenced by the degree of imperviousness of the surface: the proportion of runoff resulting from a given amount of rainfall may be expected to increase as the proportion of impervious surface increases. Since urbanization is normally accompanied by an increase in area covered by impervious surfaces, it follows that urbanization will result in larger volumes of runoff for given rainfall events.

The time of concentration[10] of a watershed or subwatershed area varies with the hydraulic resistance characteristics of its surfaces, which are in turn determined by land use. Smooth surfaces, such as paved areas and the paved channels, gutters, and sewers of more efficient urban drainage systems reduce the time of concentration and cause the runoff hydrograph to have a shorter base and a higher peak as compared to vegetated areas, natural channels, and improved open ditches. In summary, then, the increase in imperviousness and increased efficiency of drainage systems associated with the urbanization process increases runoff volumes and decreases runoff times. These two hydraulic effects of urbanization are additive with the result that incremental urbanization can cause large increases in flood volumes, discharges, stages, and areas subject to inundation.

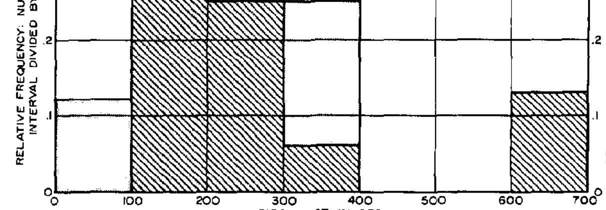
A recent simulation study[11] of the 44 square mile Morrison Creek watershed in California—presently about 20 percent urbanized—illustrates the potential dramatic effect of overall urbanization on the downstream flood flow regime. Urbanization would shift the Morrison Creek discharge-frequency relationship such that the discharge having a recurrence interval of 100 years under existing conditions of 20 percent urbanization would be reached or exceeded once in the average of every two years under conditions of complete urbanization.

Historic streamflow observations for portions of the Menomonee River watershed provide some evidence of the impact of urbanization on flood flows. Consider, for example, annual instantaneous peak discharges of the Little Menomonee River and Honey Creek as discussed earlier in this chapter and set forth in Table 27. The gaging station on the Little Menomonee River monitors flow from a 7.96 square mile rural area, whereas the Honey Creek gaging station receives discharges from a 3.34 square mile urban area. Although the Little Menomonee River tributary area is over twice the size of the Honey Creek area, the frequency distribution of annual instantaneous peak flows, as shown in Figure 33, is very similar for the two areas. The smaller Honey Creek area, in fact, exhibits a tendency to develop higher peak flows than the Little Menomonee River area. The observed similarity of flood flow regimes, in spite of the significant difference in tributary area size, reflects the hydrologic-hydraulic impact of urbanization on the smaller Honey Creek area.

The rapid rise of rainfall event floodwaters throughout much of the urban part of the watershed provides another example of the impact of urbanization on the flood flow of the basin. As noted in the earlier discussion of rainfall and rainfall-snowmelt flood event hydrographs, the former type exhibits very rapid rises with the ascending limb of the hydrograph denoting a period ranging in duration from a fraction of a day to about two days. This "flashy" response of the watershed to rainfall events probably reflects the urban development that has affected much of the watershed. From a hydraulic perspective, this

Figure 33

FREQUENCY DISTRIBUTION OF ANNUAL INSTANTANEOUS PEAK DISCHARGES ON THE LITTLE MENOMONEE RIVER AND HONEY CREEK IN THE MENOMONEE RIVER WATERSHED



Source: U. S. Geological Survey and SEWRPC.

[10] *The time of concentration is defined as the time necessary for surface runoff to reach the outlet of a drainage area from the most remote point in that drainage area, the term "remote" being used to denote most remote in time and not necessarily distance.*

[11] *Stall, John B., Terstriep, Michael L., and Huff, Floyd A., "Some Effects of Urbanization on Floods," ASCE National Water Resources Engineering Meeting, Memphis, Tennessee, January 1970.*

urban development is significant because it embodies a large amount of impervious surface and an extensive system of storm sewers and storm water drainage channels. The net effect of this efficient hydraulic system is the more rapid runoff of large volumes of rainfall into the Menomonee River and its tributaries than would flow from a rural or less densely developed urban area of similar size.

Although the ultimate adverse effect of widespread urbanization may be predicted for any particular watershed, the urbanization process usually proceeds without the benefit of such analysis. Land use patterns are, instead, the results of a myriad of decisions made independently by many different public and private parties. The attendant downstream consequences accumulate relatively slowly over a period of years until increasing downstream flood problems become manifest. Because of this absence of an integrated approach to the planning for and design of urban development, flood problems gradually develop over a period of time until the demand for flood control works becomes so great as to require public action. The Menomonee River watershed planning program includes, as described in Chapter VIII, "Water Resource Simulation Model" a comprehensive analysis of the impact of land use on flood phenomena.

Groundwater Phase of the Hydrologic Cycle

That part of precipitation that infiltrates into the ground and escapes becoming evapotranspiration or part of the soil moisture percolates downward until it reaches the zone of saturation and becomes part of the groundwater reservoir. The inventory and analysis of the groundwater resources of the Menomonee River watershed are presented in two phases in this chapter: groundwater hydrology and groundwater hydraulics.

Groundwater hydrology, as described below, has to do with the vertical and horizontal extent of the significant aquifers underlying the watershed, their relative positions, and the quantities of water contained within them. In contrast, groundwater hydraulics, treated later in this chapter, relates to such factors as the flow resistance of the aquifers and the flow patterns associated with those aquifers.

Principles of Occurrence: Groundwater in saturated rock occupies the pore spaces and other openings in the rock materials. Similarly, in loose, unconsolidated materials, groundwater occupies the spaces between individual grains of silt, clay, sand, or gravel. In rock, the openings that are filled include those along bedding planes, fractures, faults, joints, and solution cavities. Solution cavities are important in the dolomite formations of the Menomonee River watershed. Intergranular pore openings in rocks may be fewer and smaller than those in unconsolidated materials because they are often constricted by cementing material, such as calcite and silica. In rocks such as dolomite, which contain little or no intergranular pore space, the groundwater occupies primarily the fractures and crevices that pass through such rocks.

Groundwater occurs under water table conditions whenever the surface of the zone of saturation is at atmospheric pressure. Groundwater occurs under confined or artesian conditions wherever a saturated formation is directly overlain by a relatively impermeable formation which confines the water in the permeable unit under pressure greater than atmospheric pressure. Flow of groundwater from an artesian aquifer is similar to gravity flow from a high elevation reservoir through a pipe distribution system. The static water level in wells tapping artesian aquifers always rises above the top of the artesian aquifer. Discharge from artesian aquifers is controlled by the confining stratum, and most of the recharge of the artesian aquifer occurs where the confining stratum is missing.

Uncased wells provide conduits for the movement of groundwater between aquifers in a multiaquifer system, such as that present in the Menomonee River watershed, both upward under artesian head and downward under gravity flow conditions.

Flowing wells result if the static water level at the well is higher than the land surface. Flow continues until that water level is lowered below the land surface. Groundwater is released from storage in water table and artesian aquifers as the result of different physical processes. In a water table aquifer, groundwater is released to wells by gravity drainage of the aquifer pore spaces. In an artesian aquifer, water is released to the well as the result of compression of the aquifer and expansion of groundwater.

An aquifer consisting of tightly packed, well-sorted spherical particles of sand may contain up to 40 percent water by volume—about three gallons per cubic foot of aquifer. Given sufficient time, about one-half of this volume of water may be drained by gravity from a water table aquifer with the other half adhering to the aquifer against the force of gravity. The quantity of groundwater released from a cubic foot of similar materials under artesian conditions is extremely small by comparison because under artesian conditions the aquifer is not drained but the released water is instead attributable solely to the expansion of the water and the compression of the solid material comprising the aquifer. This expansion of the water and contraction of the aquifer material is in response to the reduced water pressure caused by pumping the aquifer. The practical consequence of this difference in the origin of water taken from an unconfined aquifer, compared to a confined or artesian aquifer, is that pumping from an artesian aquifer affects an immense area compared to the area affected by pumping at an equivalent rate from a water table aquifer of similar vertical and horizontal extent and material.

There are three principal aquifers underlying the Menomonee River watershed: the sandstone aquifer, the deepest of the three; the dolomite aquifer; and the sand and gravel aquifer, the shallowest of the three. The latter two are hydraulically interconnected and, therefore, are sometimes considered to comprise a single aquifer. The dolomite aquifer is also commonly, but incorrectly, called the "limestone" aquifer. The deep sandstone aquifer is separated from the shallower dolomite aquifer by a layer of relatively impermeable shale. The more important of the three aquifers are the sandstone and the dolomite aquifers, which underlie the entire watershed and are generally available for use in any locality. The sand and gravel aquifer is of lesser importance because, although it reaches a thickness of 250 feet in some watershed areas, it is very thin or nonexistent in other areas. Furthermore, it does not yield large quantities of water, and it is particularly susceptible to pollution from overlying rural and urban land uses.

The stratigraphic units comprising each of the three aquifers as well as selected hydrologic and hydraulic information about each is summarized in Table 28. Figure 34 shows a well log for a 1,400 foot deep well in the Village of Menomonee Falls that passes through all three of the major aquifers. Hydrologic characteristics of each of the three principal aquifers are discussed below.

The Sandstone Aquifer: In the Menomonee River watershed, the sandstone aquifer includes all the geologic units bounded above by the Maquoketa shale and bounded below by the Precambrian rocks. Although it is commonly referred to as the sandstone aquifer, some of the units contained within it—for example, the Galena dolomite—are not sandstone. Some wells in the sandstone aquifer in the Milwaukee area are reported to yield over 1,800 gallons per minute (GPM) or about 2.6 million gallons per day (MGD). The Maquoketa shale confines water in

Table 28

STRATIGRAPHIC UNITS AND HYDROLOGIC-HYDRAULIC CHARACTERISTICS OF THE MAJOR AQUIFERS IN THE MENOMONEE RIVER WATERSHED

Major Aquifer	Stratigraphic Unit	Water-Bearing Characteristics	Range of Aquifer Hydrologic-Hydraulic Characteristics: Saturated Thickness (Ft.)	Porosity	Average Transmissivity (GPD/Ft.)	Storage Coefficient	Average Recharge Rate (GPD/Sq. Mi.)
Sand and Gravel	Alluvium	Saturated sand and gravel units very permeable but thin. Not important as an aquifer.	0- 180	0.20-0.45	10,000-200,000	0.0001-0.20	48,000-191,000
	Glacial Deposits	Saturated sand and gravel units very permeable.					
Dolomite	Dolomite Undifferentiated	Permeability generally low. Solution cavities and crevices present throughout but density of openings is irregular. Important aquifer unit.	150- 450	0.05	2,000- 10,000	0.0001-0.005	< 10,000-143,000
Sandstone	Galena Dolomite Decorah Formation Platteville Formation	Permeability low.					
	St. Peter Sandstone	Permeability moderate to low. Important aquifer unit.	700-1,600	0.15	3,000- 25,000	0.0001-0.00001	< 3,000
	Trempealeau Formation	Permeability low.					
	Franconia Sandstone	Permeability low.					
	Galesville Sandstone	Permeability moderate.					
	Eau Clare Sandstone	Permeability moderately low.					
	Mt. Simon Sandstone	Permeability moderate. Important aquifer unit.					

Source: U. S. Geological Survey.

the sandstone aquifer under artesian pressure and is normally cased off in wells to prevent destruction of the well by caving of the formation.

The surface of the sandstone aquifer is located approximately 700 to 800 feet beneath the ground surface of the Menomonee River watershed. As shown on the geologic cross sections of Figure 13 and on Map 31, which shows the topography of the surface of the sandstone aquifer, the aquifer dips gently downward in an easterly direction. The slope of the bottom of the aquifer approximates 100 feet per mile, whereas the slope of the top of the aquifer approximates 10 feet per mile. Because of the difference in slopes of the two boundary surfaces, the portion of the sandstone aquifer beneath the Menomonee River watershed increases in thickness, as shown on Map 32, in a generally easterly-southeasterly direction, ranging from a minimum of about 700 feet in the northwestern portion of the watershed to more than 1,500 feet in the southeastern portion of the watershed.

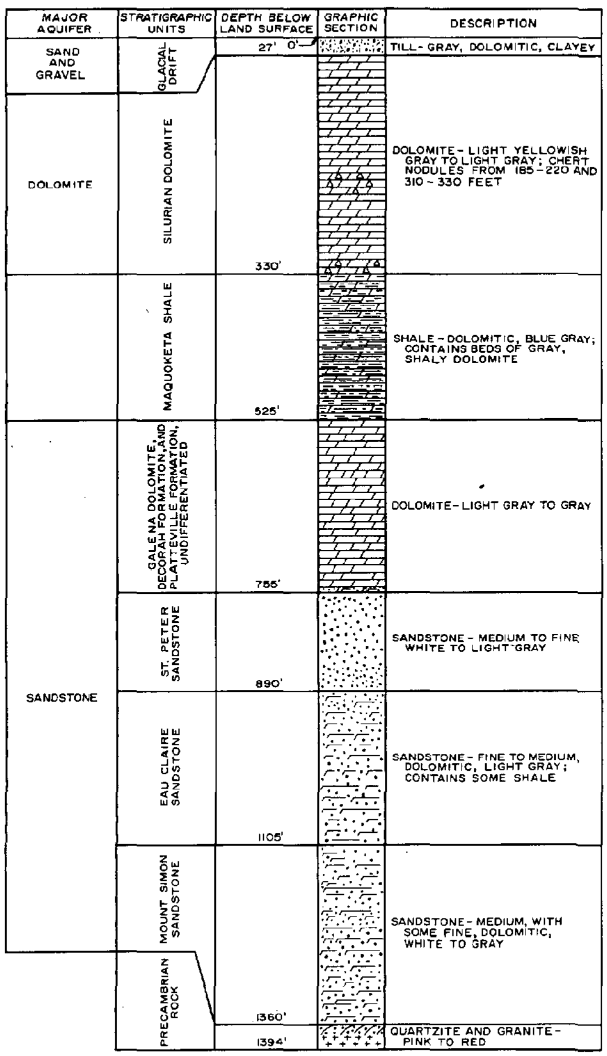
The average thickness of the sandstone aquifer beneath the watershed is about 1,070 feet. Assuming an average porosity of 15 percent, about 14,100,000 acre-feet of water are contained within that portion of the aquifer lying immediately beneath the Menomonee River watershed. This volume of water would be sufficient to cover the entire watershed to a depth of 160 feet.

The total amount of recharge to the sandstone aquifer—presently less than its discharge—enters the aquifer system in three ways. It occurs as infiltration of precipitation through glacial deposits in a recharge area located west of the watershed, where the Maquoketa shale and younger formations are absent. Secondly, a small amount of recharge occurs as vertical leakage through the Maquoketa shale because of the hydraulic head difference existing between the top and bottom of this shale as discussed later in this chapter. Thirdly, and also because of that hydraulic head difference, deep wells uncased in both the dolomite and sandstone aquifers allow movement of water from the dolomite aquifer immediately above the Maquoketa shale to the sandstone aquifer beneath.

As noted above, water in the sandstone aquifer occurs under artesian conditions because of the confining effect of the overlying and relatively impermeable Maquoketa shale. The approximate thickness of the Maquoketa shale is shown on Map 33 and ranges from 150 to 200 feet. The confining Maquoketa shale slopes downward in a generally easterly-southeasterly direction at about 10 feet per mite. Map 34 shows the topography of the surface of the Maquoketa shale and in effect, also the lower surface of the dolomite aquifer which lies immediately above the shale.

Figure 34

MENOMONEE FALLS WELL NO. 2 LOG, SHOWING CHARACTERISTICS OF THREE AQUIFERS INTERSECTED BY WELL



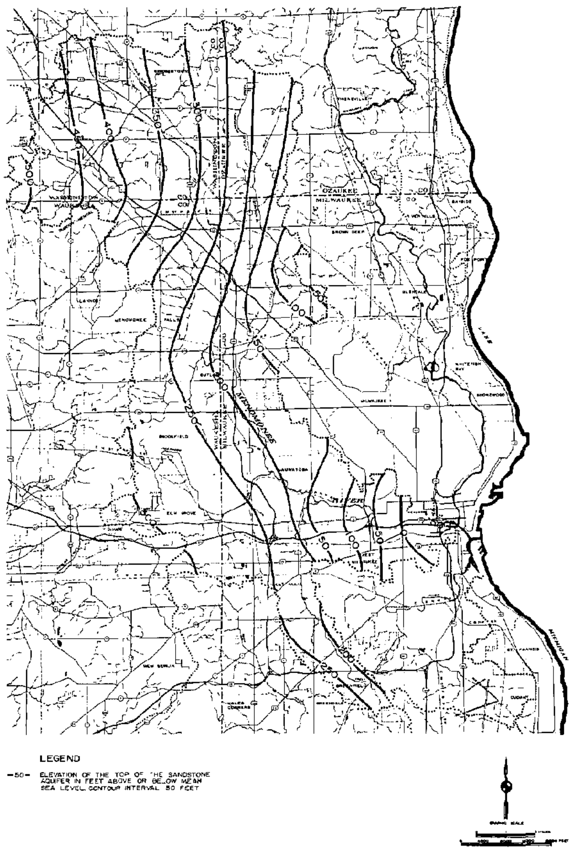
Source: Wisconsin Geological Survey.

<u>The Dolomite Aquifer:</u> The dolomite aquifer underlies the entire Menomonee River watershed and consists mainly of Silurian dolomite but also includes a few small outliers of Devonian dolomite over the Silurian dolomite in the southeastern part of the watershed. The relatively impermeable Maquoketa shale is positioned immediately below the aquifer whereas unconsolidated glacial till, drift and alluvial deposits, varying in thickness from zero to 250 feet, lie immediately above.

The geologic cross-sections of Figure 13 and Map 35, which shows the topography of the surface of the dolomite aquifer, indicate that the aquifer dips gently downward in a generally easterly-southeasterly direction at about 10 feet per mile. Aquifer thickness, as shown on Map 36, is variable ranging from a minimum of about 100 feet in the southeastern portion of the watershed and in parts of the Village of Menomonee Falls to a maximum of over 450 feet in the City of Mequon.

Map 31

TOPOGRAPHY OF THE SURFACE OF THE SANDSTONE AQUIFER IN THE MENOMONEE RIVER WATERSHED

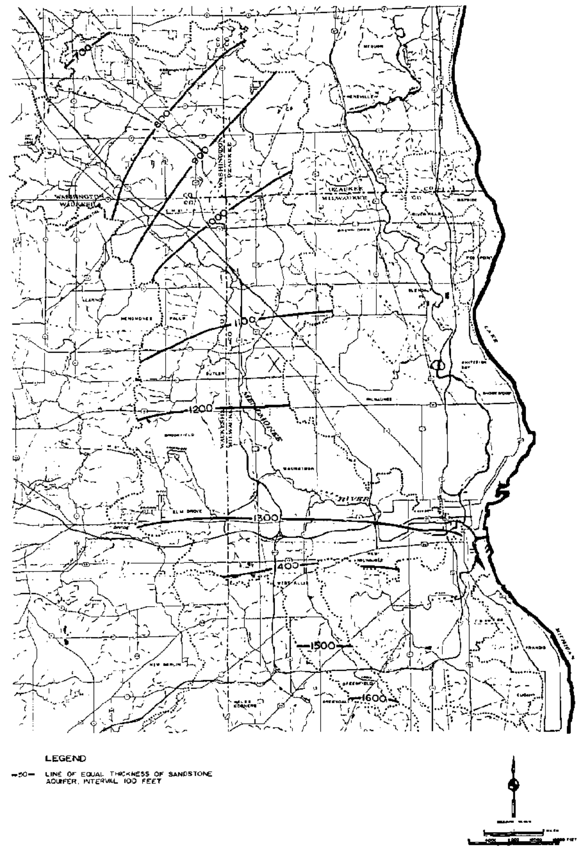


The surface of the sandstone aquifer is located approximately 700 to 800 feet beneath the ground surface of the Menomonee River watershed. As shown by the contour lines, the surface of the aquifer dips gently downward in an easterly-southeasterly direction.

Source: U. S. Geological Survey.

Map 32

THICKNESS OF THE SANDSTONE AQUIFER IN THE MENOMONEE RIVER WATERSHED



The thickness of the sandstone aquifer increases in a generally easterly-southeasterly direction across the watershed, ranging from a minimum of 700 feet in the Germantown area to more than 1,500 feet in the Greenfield area of the watershed. The average thickness of the sandstone aquifer beneath the watershed is about 1,100 feet.

Source: U. S. Geological Survey.

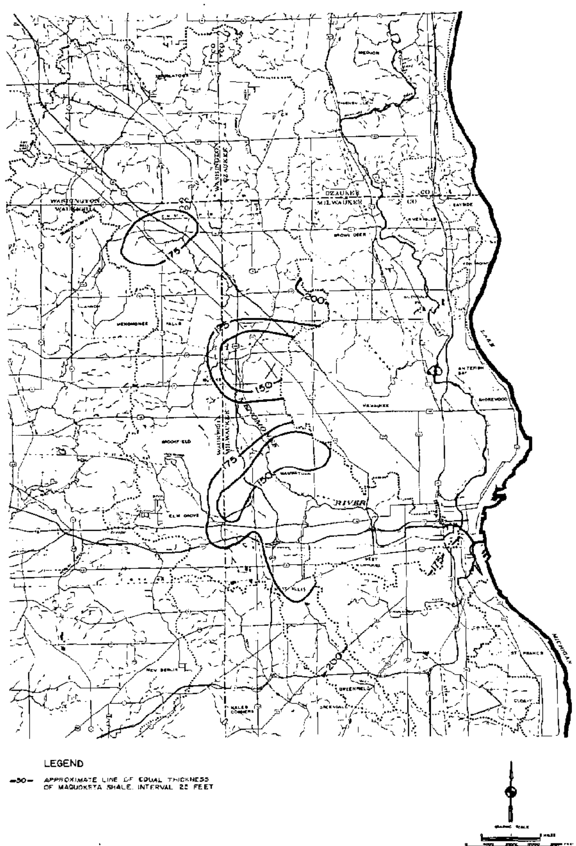
The most striking feature of the surface of the dolomite aquifer is a steep slope, or precipice, that is oriented in a southwesterly-northeasterly direction and that passes through the upper watershed in the Village of Menomonee Falls. The surface of the dolomite aquifer drops from an elevation of about 800 feet above mean sea level datum to about 650 feet above that datum over a distance of about one-half mile in the Village of Menomonee Falls. This feature of the dolomite reflects erosion of its surface prior to the deposition of the overlying glacial drift and alluvial materials. Some of the steepest channel slopes of the Menomonee River watershed stream system occur in Menomonee Falls where the Menomonee River flows directly on and down the steep slope of the dolomite bedrock surface.

The average thickness of the zone of saturation of the dolomite aquifer in the watershed is 285 feet. Assuming an average porosity of 5 percent, about 1,250,000 acre-feet of water exist within the watershed portion of the dolomite aquifer. This quantity of water would be sufficient to cover the entire watershed to a depth of 14 feet.

Recharge to the dolomite aquifer is primarily from infiltration of precipitation through overlying glacial deposits. Although the rate of recharge under nonpumping conditions probably is very small, pumping the aquifer induces recharge as vertical leakage from the overlying glacial deposits. Recharge will be greatest wherever sand and gravel deposits overlie the dolomite aquifer, and it will be least where the dolomite is overlain by clay or till.

Map 33

THICKNESS OF THE MAQUOKETA SHALE
IN THE MENOMONEE RIVER WATERSHED

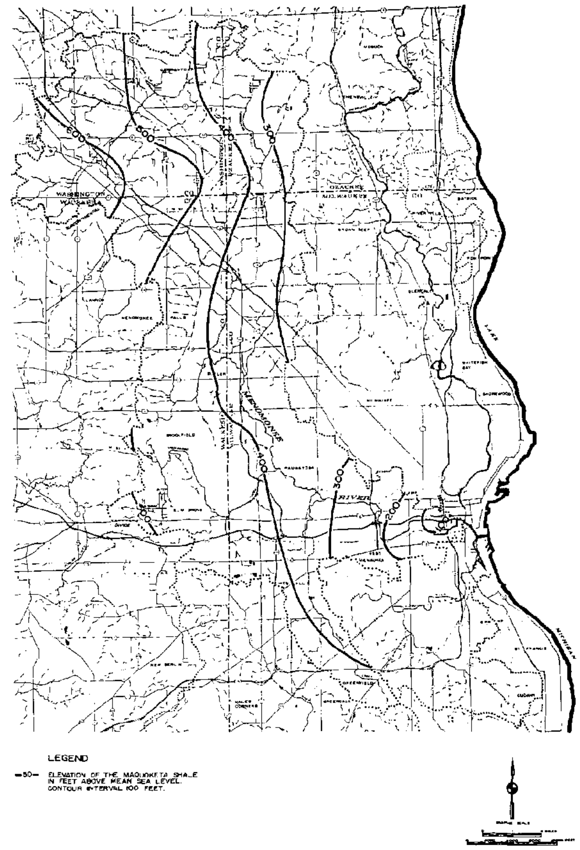


The Maquoketa shale formation underlying the watershed ranges in thickness from 150 to 200 feet, and slopes downward in a generally easterly-southeasterly direction across the watershed at about 10 feet per mile. The relatively impermeable shale formation separates the two interconnected shallow aquifers underlying the watershed from the deep aquifer. Water in the deep sandstone aquifer, which lies beneath he shale, occurs under artesian conditions because of the confining effect of the shale.

Source: U. S. Geological Survey.

Map 34

TOPOGRAPHY OF THE SURFACE OF THE MAQUOKETA
SHALE IN THE MENOMONEE RIVER WATERSHED



The surface of the Maquoketa shale is located approximately 500 to 600 feet beneath the ground surface of the Menomonee River watershed. The shale separates the deep, confined sandstone aquifer which is recharged primarily in areas lying outside of the watershed from the shallow, unconfined aquifers which are recharged locally.

Source: U. S. Geological Survey.

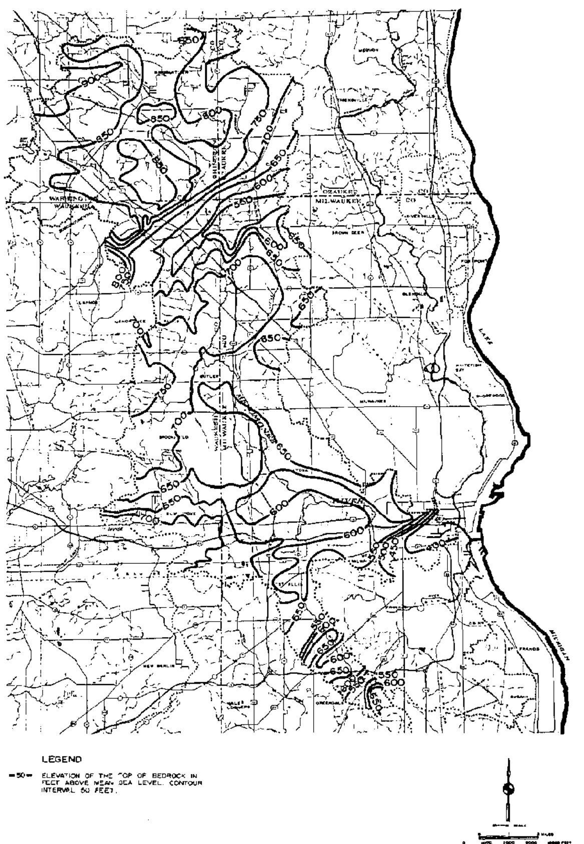
Small quantities of recharge through infiltration of streamflow may also occur where streams and abandoned water-filled quarries are cut into the dolomite. The Menomonee River flows on dolomite bedrock in several places in the watershed including in the Village of Menomonee Falls and in the City of Wauwatosa. Furthermore, as discussed in Chapter III, "Description of the Watershed," several abandoned dolomite quarries are located within the watershed and are potential locations where surface water gains direct access to the dolomite aquifer.

The Sand and Gravel Aquifer: The sand and gravel aquifer consists of stratified, unconsolidated glacial and alluvial sand and gravel deposits. This aquifer can be developed by large-capacity wells only where the grain size of the materials is larger than very fine sand. The most significant aquifer units are those that underlie areas more than one-half square mile in extent.

As shown on the geologic cross-sections of Figure 13, and on Map 37, the thickness of the sand and gravel is extremely variable throughout the Menomonee River watershed. Some areas of the watershed are overlain by over 200 feet of sand and gravel including areas just west of the Menomonee River in the Village of Menomonee Falls, in the western extremity of the watershed in the City of Brookfield, in the headwater areas of Honey Creek in the Cities of Greenfield and Milwaukee, and in

Map 35

TOPOGRAPHY OF THE SURFACE OF THE DOLOMITE AQUIFER IN THE MENOMONEE RIVER WATERSHED

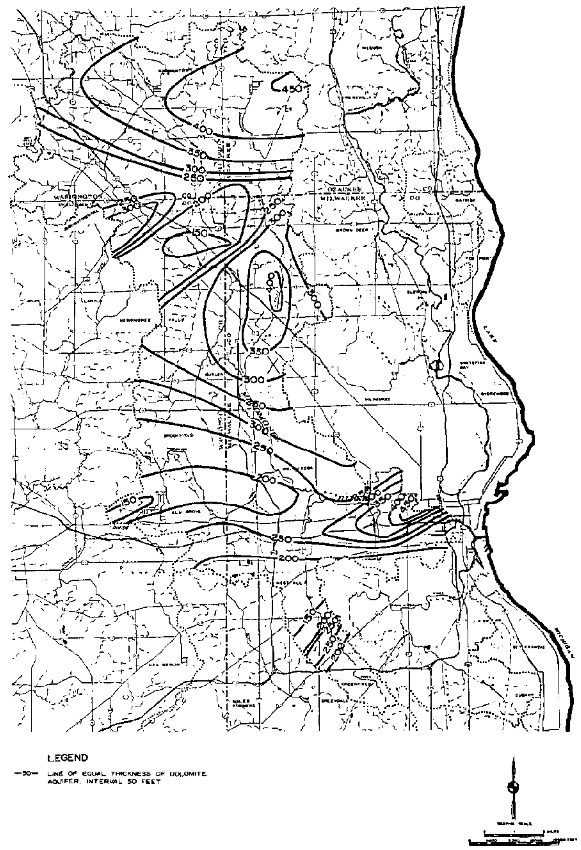


The surface of the dolomite aquifer is located from zero to 250 feet beneath the ground surface of the Menomonee River watershed. The aquifer dips gently downward in a generally easterly-southeasterly direction across the watershed at about 10 feet per mile. The relatively impermeable Maquoketa shale is positioned immediately below the aquifer, whereas unconsolidated glacial till, drift, and alluvial deposits lie immediately above.

Source: U. S. Geological Survey.

Map 36

THICKNESS OF THE DOLOMITE AQUIFER IN THE MENOMONEE RIVER WATERSHED



The thickness of the dolomite aquifer ranges from a minimum of about 100 feet in the southeastern portion of the watershed and in parts of the Village of Menomonee Falls to a maximum of over 450 feet in the City of Mequon. The dolomite aquifer underlies the entire Menomonee River watershed and consists mainly of Silurian dolomite. It, together with the overlying glacial till, forms a shallow aquifer which is recharged locally.

Source: SEWRPC.

the high ground immediately south of the Menomonee River industrial valley in the City of Milwaukee. Other portions of the watershed are covered by a relatively thin layer of sand and gravel. Most of the watershed portion of the Village of Germantown, for example, is covered by less than 50 feet of sand and gravel.

The bottom surface of the sand and gravel aquifer is quite irregular, reflecting the eroded upper surface of the dolomite aquifer. In contrast, the upper surface of the sand and gravel aquifer is relatively smooth and continuous except where localized discontinuities exist as a result of the presence of incised streams and the associated riverine areas. Map 15, which depicts the generalized surface topography of the Menomonee River watershed and therefore the surface of the sand and gravel and other glacial deposits, indicates that the aquifer surface slopes gently downward in a generally easterly-southeasterly direction.

The thickness of the sand and gravel overlying the watershed ranges from 0 to 250 feet whereas the average thickness of the zone of saturation in the sand and gravel is about 53 feet. Assuming an average porosity of 0.30, about 1,394,000 acre-feet of water exists within the saturated strata of the sand and gravel. This quantity of water would be sufficient to cover the watershed to a depth of 16 feet.

Direct infiltration of precipitation is the major source of recharge to the sand and gravel aquifer. Recharge is greatest where the sand and gravel deposits and associated permeable soils occur at the surface; it is smallest where fine-grained soils, clay, silt, or till form the surficial deposits. Locally unsaturated sand and gravel deposits with poorly developed surface drainage and numerous kettle holes may be expected to have a high rate groundwater recharge. In the Menomonee River watershed, recharge to the glacial deposits occurs primarily during the spring months after frost has left the ground and before evapotranspiration rates become high. The principal recharge period usually occurs during March, April, and May. Recharge takes place during other seasons but the amount is comparatively small.

Groundwater recharge also occurs from surface water sources in areas where the water table is lower in elevation than a nearby surface water body. Wherever this condition exists, discharge from the surface water source to the groundwater can take place. Stream reaches where this condition occurs are known as influent or losing stream reaches. Some of the principal streams in the watershed are known to have influent reaches as discussed in Chapter VII of this volume.

HYDRAULICS OF THE WATERSHED

As defined earlier in this chapter, hydraulics—in the context of comprehensive watershed planning—involves the inventory and analysis of those factors that affect the physical behavior of water as it flows within stream channels and on the attendant natural floodplains, under and over bridges, culverts and dams; through lakes and other impoundments, and within the watershed aquifer system. The preceding portion of this chapter has concentrated on the hydrology of the Menomonee River watershed under the broad categories of surface water and groundwater hydrology. This section of the chapter describes the results of the inventory and initial analysis of watershed hydraulics including both surface water and groundwater hydraulics.

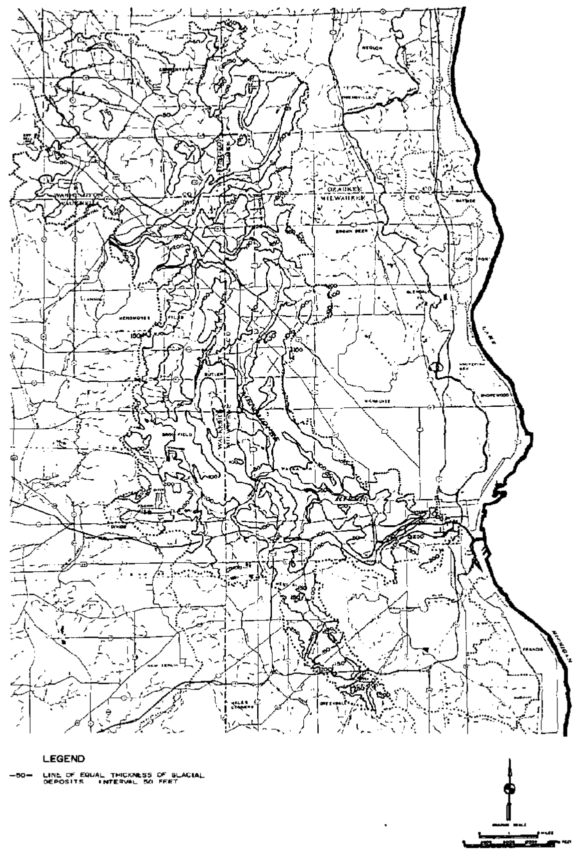
Surface Water Hydraulics

An overview of the watershed surface water resources is presented in Chapter III, "Description of the Watershed." Inasmuch as there are no major lakes in the Menomonee River watershed, the surface water system of the watershed consists essentially of the streams and associated natural floodplains. The hydraulic characteristics of those streams and floodplains are described below.

Portion of the Stream System Selected for Development of Detailed Flood Hazard Data: The lineal extent of the perennial and intermittent streams in the watershed is extensive if each tributary to the Menomonee River is traced upstream to its origin. The cost of hydrologic-hydraulic simulation (which includes the costs of data collection, collation and coding; the cost of computer runs; and the cost of analyzing model results) increases in proportion to the lineal miles of streams that are modeled. Therefore, a decision was required on the portion of the watershed stream system for which detailed flood hazard information would be developed by hydrologic-hydraulic simulation studies prior to inventorying the hydraulic features of the stream system. Detailed flood hazard data

Map 37

THICKNESS OF GLACIAL DEPOSITS IN THE MENOMONEE RIVER WATERSHED



The thickness of the glacial deposits which form the surface of the watershed, and which are often comprised of sand and gravel, is extremely variable throughout the watershed. Some areas of the watershed are overlain by over 200 feet of glacial till while other portions of the watershed are covered by a relatively thin layer of the material. Most of the Village of Germantown, for example, is covered by less than 50 feet of glacial till.

Source: SEWRPC.

are defined to include discharge-frequency relationships under existing and probable future land use conditions and corresponding flood stage profiles and areas subject to inundation by floods of selected recurrence interval.

Selection Criteria: Seven factors were considered in selecting streams and stream reaches of the Menomonee River watershed for development, through hydrologic-hydraulic modeling techniques, of detailed flood hazard information:

1. The hydraulic importance of the stream in the context of the total watershed stream system. Most of the main stem of the Menomonee River, for example, would have to be included, as

a practical matter, for hydrologic-hydraulic simulation modeling since flood stages on the Menomonee River significantly affect flood stages for the lower portions of tributary streams.

2. Existing flood problems. The Underwood Creek reach, for example, passing through the business district of the Village of Elm Grove, was considered for the development of detailed flood hazard data because of the floodprone nature of that area as evidenced by serious flood problems in April 1973. Detailed flood hazard information is needed for this and other similar reaches to permit proper consideration of alternative solutions to the existing flood problems.

3. Potential flood problems related to planned land use development. The adopted regional land use plan, for example, envisions new urban development adjacent to the Menomonee River environmental corridor in portions of the Village of Germantown. Detailed flood hazard information is needed for this and other similar reaches to assure that such planned development, in close proximity to the floodlands of the river, can be designed and developed so as not to be subject to flood damage.

4. Availability, without cost to the watershed planning program, of large scale topographic maps of riverine areas or of other similar information such as detailed engineering plans or as-built drawings of major channelization projects. For example, a relatively large number of streams and a considerable length of each stream in the Village of Germantown, were considered for the development of detailed flood hazard data because of the availability from the Village of the necessary large scale topographic maps.

5. Availability, without cost to the watershed planning program study, of a significant amount of definitive data on existing hydraulic structures such as bridges, culverts, and dams. The Village of Menomonee Falls, for example, conducted field surveys and provided detailed bridge and culvert data for two Menomonee River tributaries lying within the Village Limits--Lilly Creek and Nor-X-Way Channel. Largely as a result of the provision of this data, together with large scale topographic maps by the Village, consideration was given to the development of detailed flood hazard data for these two tributaries.

6. Implementation of the primary environmental corridor concept. As discussed in Chapter III, "Description of the Watershed," floodlands constitute one of 11 factors utilized by the SEWRPC to delineate primary environmental corridors. More specifically, floodland limits developed under the comprehensive watershed planning program of the Commission were used to refine environmental corridor limits originally established in the adopted regional land use plan. The need to refine primary environmental corridors was one of the most important factors that entered into selection of stream reaches for development of detailed flood hazard information. For example, hydrologic-hydraulic simulation was considered far up into the headwaters of the Menomonee River main stem so as to provide the floodland data needed to refine the primary environmental corridor that had been identified along the river in the adopted regional land use plan.

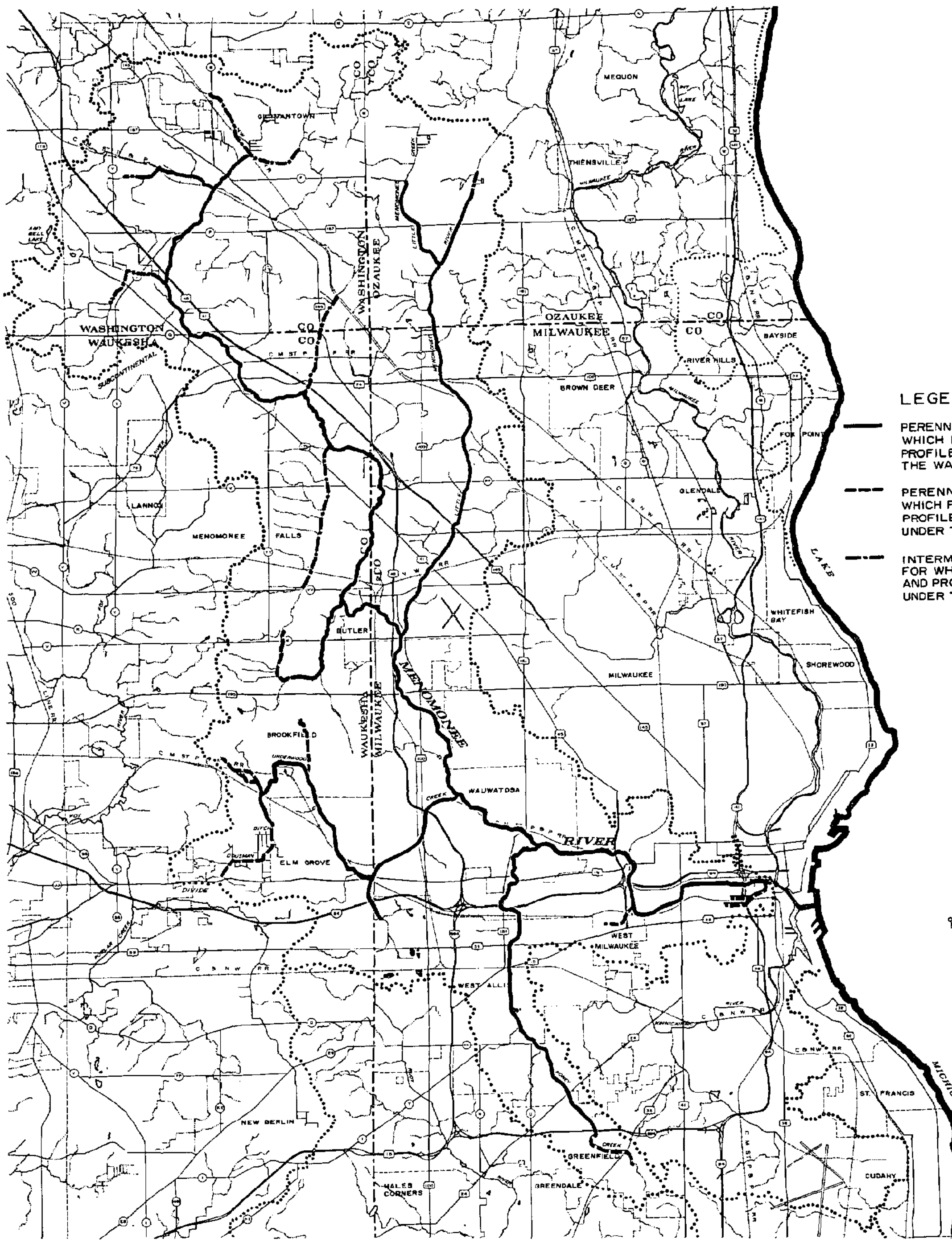
7. Wisconsin Department of Natural Resources (DNR) tributary area guideline: As a general rule, the DNR requires preparation and adoption of floodland use regulations along streams where serious flood damage may occur and for which the tributary drainage area is in excess of approximately two square miles. This guideline was applied to the Menomonee River watershed during selection of stream reaches for development of flood hazard information. For example, hydrologic-hydraulic simulation was extended far up Honey Creek so as to terminate at a point where the tributary area, currently undergoing urbanization, is about two square miles in extent.

It should be noted that the above selection criteria are independent of the perennial or intermittent nature of the stream as defined on U. S. Geological Survey quadrangle maps. The perennial or intermittent classification of a stream, particularly in an urban area, is of minor consequence relative to the above seven factors because classification is not an index to either the severity of existing or potential flood problems in an urban area or an indication of the availability of data for analyzing and resolving those problems. The seven factors do represent these two tests.

Selected Reaches: Based on the above criteria, parts of 13 streams within the Menomonee River watershed were selected for hydrologic-hydraulic simulation leading to the development of detailed flood hazard information including discharge-frequency relationships under existing, planned future and unplanned future land use development; and corresponding flood stage profiles and areas of inundation. These streams are shown on Map 38 and include the main stem of the Menomonee River which, in downstream order, flows through the Villages of Germantown and Menomonee Falls and the Cities of Wauwatosa and Milwaukee. Also included are the North Branch and West Branch of the Menomonee River and Willow Creek, three Menomonee River tributaries lying within the Village of Germantown; Lilly Creek, Nor-X-Way Channel, and Butler Ditch, three Menomonee River tributaries lying largely within the Village of Menomonee Falls; the Little Menomonee River which is tributary to the Menomonee River and flows through the Cities of Mequon and Milwaukee; Little Menomonee Creek, a Little Menomonee River tributary in Mequon, Underwood Creek which passes through the City of Brookfield, the Village of Elm Grove, and the City of Wauwatosa; the South Branch of Underwood Creek located in the Cities

Map 38

STREAM REACHES IN THE MENOMONEE RIVER WATERSHED SELECTED FOR PREPARATION OF FLOOD HAZARD INFORMATION



LEGEND

- PERENNIAL STREAM REACHES FOR WHICH FLOOD DISCHARGES AND PROFILES WERE DEVELOPED UNDER THE WATERSHED STUDY
- PERENNIAL STREAM REACHES FOR WHICH FLOOD DISCHARGES AND PROFILES WERE NOT DEVELOPED UNDER THE WATERSHED STUDY
- INTERMITTENT STREAM REACHES FOR WHICH FLOOD DISCHARGES AND PROFILES WERE DEVELOPED UNDER THE WATESHED STUDY

GRAPHIC SCALE

0 1 2 MILES

0 4000 8000 12000 16000 FEET

A total of 71.85 miles of streams in the Menomonee River watershed, including 60.06 miles of perennial streams and 11.79 miles of intermittent streams, were selected for the development of detailed flood hazard information. A detailed engineering inventory was conducted of the 71.85 miles of selected stream reach to determine the storage and conveyance characteristics of the floodlands and the hydraulic capacity of all bridges, culverts, dams, and drop structures.

Source: SEWRPC.

of Brookfield and West Allis; and Honey Creek, a Menomonee River tributary passing through the Cities of Greenfield, Milwaukee, West Allis, and Wauwatosa. Table 29 and Table 30 present more detailed information on the selected stream reaches and the tributary drainage areas, and, as indicated therein, detailed flood hazard information was developed for a total of 60.06 miles of perennial streams and 11.79 miles of intermittent streams, or for a total of 71.85 miles of streams in the Menomonee River watershed.

Subsequent to the identification of the above 71.85 miles of stream, the Commission conducted a detailed engineering inventory of the selected reaches. This inventory included collection, collation, and preliminary analysis of floodland characteristics as well as definitive data on bridges and culverts and physical information about dams and drop structures.

Floodland Characteristics: Included in the category of floodland characteristics are the magnitude and variation of channel slope, floodland shape and roughness, and the extent and nature of channel improvements. For a given discharge, each of these floodland characteristics can be a primary determinant of river stage.

Channel Profiles: Figure 35 shows channel profiles for the 14 stream reaches and 71.85 miles of perennial and intermittent stream selected for the development of detailed flood hazard information. The primary source of data for these channel bottom profiles was channel bottom elevations at bridges, culverts, dams, and drop structures which were determined by field surveys as part of the watershed hydraulic structure inventory.

Channel slopes are irregular with steeper slopes near the headwater areas and generally flatter slopes in the middle and lower reaches of each stream. All other hydraulic factors being equal or similar, steep channel slopes result in high stream flow velocities and shorter runoff times, whereas flat slopes produce lower velocities and longer runoff times. The steepest channel slopes in the Menomonee River stream system approximate 100 feet per mile and are found along a 0.6 mile segment of the Upper Menomonee River in the Village of Menomonee Falls. A 0.7 mile headwater reach of Underwood Creek has a slope of 70 feet per mile. Average slopes for each of the 14 stream reaches as given in Table 29 vary from a minimum of about 3.5 feet per mile for the Little Menomonee River to a maximum of about 21 feet per mile for the North Branch of the Menomonee River. The median slope is about 15 feet per mile.

Although the channel profiles do illustrate the magnitude and variation of slopes throughout the watershed stream system, the primary purpose of developing the profiles was to provide a basis for estimating channel bottom elevations at points in between the bridges, culverts, dams, and drop structures at which channel bottom elevations were determined by field surveys. Channel bottom elevations for these intermediate locations—as obtained from the channel bottom profiles—were required for the development of floodland cross-sections as discussed below.

Floodland Cross-Sections: The size and shape of the floodlands, that is, the channel and its natural floodplain, particularly the latter, are important floodland characteristics, being the primary determinants of flood stage and the lateral extent of inundation for a given flood discharge. Approximately 933 floodland cross-sections at an average spacing of 500 feet were developed for the 71.85 miles of stream in the Menomonee River watershed selected, as described above, for the development of detailed flood hazard information. The aforementioned cross-sections exclude those immediately upstream and downstream of bridges, culverts, and other hydraulic structures inasmuch as the latter are intended to represent the configuration of the riverine area near and around the structure in contrast with cross-sections located 50 or more feet upstream and downstream of structures which are intended to reflect the full conveyance of the unobstructed floodland area. After conversion to numerical form, these cross-sections were input to the hydraulic submodel of the hydrologic-hydraulic simulation model as described in Chapter VIII, "Water Resource Simulation Model."

Floodland cross-sections were developed from several sources including riverine area large scale topographic maps some of which were obtained under the watershed study, photogrammetric cross-sections obtained under the watershed study, and channel improvement plans. The channel bottom elevation for each cross-section was obtained from the channel profiles prepared under the study. Map 39 shows the primary source of floodland cross-section data by river reach throughout the 71.85 miles of stream for which detailed flood hazard information was developed. A floodland cross-section, typical of those that were drawn prior to coding the data for input to the hydraulic submodel, is shown on Figure 36.

Numerous factors were considered in selection of the location, length, and orientation of floodland cross-sections. These factors included strictly hydraulic considerations as well as nonhydraulic plan preparation and implementation considerations.

A principle hydraulic consideration was the selection of locations representative of the reach encompassed by the cross-section. Other hydraulic factors influencing cross-section location included placement at abrupt changes in cross-sectional area or shape of the channel or natural floodplain; at abrupt changes in channel or attendant natural floodplain roughness; and at discontinuities in channel slope. Cross-sections were generally located at close regular intervals so as to assure that computed flood stages would be of sufficient accuracy to be useful in all phases of floodland management including the delineation of floodland regulatory zones and to facilitate, subsequent to completion of the watershed plan, the hydraulic evaluation of proposed floodland developments or other riverine area changes. Nonhydraulic factors entering into the location of floodland cross-sections included placement at points where civil division boundaries intersect the streams to permit the evaluation of the hydraulic effect of proposed riverine area developments in one community on upstream or downstream communi-

Table 29

SELECTED HYDRAULIC DATA FOR THE MENOMONEE RIVER WATERSHED BY SUBWATERSHED: 1974

Subwatershed		Stream Reach for Which Flood Stage Profiles Were Developed											Stream Slope[b] (Ft/Mile)
		Perennial[a]					Intermittent					Total (Miles)	
		Downstream End		Upstream End		Length (Miles)	Downstream End		Upstream End		Length (Miles)		
Number	Name	Location	River Mile	Location	River Mile		Location	River Mile	Location	River Mile			
1	North Branch of the Menomonee River	--	--	--	--	0.00	Confluence with the Menomonee River at River Mile 27.91	0.00	C&NW RR Bridge (Structure 2925)	1.83	1.83	1.83	21.0
2	West Branch of the Menomonee River	Confluence with the Menomonee River at River Mile 26.94	0.00	Private bridge (S-2975)	1.78	1.78	Private Bridge (Structure 2975)	1.78	Private Bridge (Structure 2982)	2.05	0.27	2.05	19.0
3	Willow Creek	--	--	--	--	0.00	Confluence with the Menomonee River at River Mile 24.70	0.00	0.5 mile south of Appleton Ave. (Structure 3320)	1.65	1.65	1.65	12.0
4	Nor-X-Way Channel	--	--	--	--	0.00	Confluence with the Menomonee River at River Mile 20.30	0.00	CMSTP&P RR Bridge (Structure 3470)	2.08	2.08	2.08	15.0
5	Lilly Creek	--	--	--	--	0.00	Confluence with the Menomonee River at River Mile 18.98	0.00	0.32 mile south of Silver Spring Road (Structure 3200)	3.29	3.29	3.29	11.0
6	Butler Ditch	Confluence with the Menomonee River at River Mile 14.41	0.00	0.61 mile west of Lilly Road	2.37	2.37	--	--	--	--	0.00	2.37	18.0
7	Upper Menomonee River	0.05 mile north of Hampton Avenue	12.57	C&NW RR Bridge (Structure 890)	27.91	15.34	C&NW RR Bridge (Structure 890)	27.91	0.46 mile north of E. Lovers Lane Road (Structure 900)	29.41	1.50	16.84	9.0
8	Little Menomonee Creek	Confluence with the Little Menomonee River at R.M.8.22	0.00	Freistadt Road (Structure 1720)	2.25	2.25	--	--	--	--	0.00	2.25	14.0
9	Little Menomonee River	Confluence with the Menomonee River at River Mile 12.52	0.00	Sunnyvale Road extended	9.65	9.65	Sunnyvale Road extended	9.65	Freistadt Rd. (Structure 1510)	10.18	0.53	10.18	3.5
10	Dousman Ditch	--	--	--	--	0.00	Confluence with Underwood Creek at River Mile 6.92	0.00	Gebhardt Rd. (Structure 1370)	0.64	0.64	0.64	4.5
11	South Branch Underwood Creek	Confluence with Underwood Creek at River Mile 2.54	0.00	W. Schlinger Avenue	1.08	1.08	--	--	--	--	0.00	1.08	5.5
12	Underwood Creek	Confluence with the Menomonee River at River Mile 8.38	0.00	Park bridge (Structure 1353)	7.47	7.47	--	--	--	--	0.00	7.47	20.5
13	Honey Creek	Confluence with the Menomonee River at River Mile 6.23	0.00	I 894 (Structure 1145)	7.55	7.55	--	--	--	--	0.00	7.55	15.0
14	Lower Menomonee River	Confluence with Milwaukee River	0.00	0.05 mile north of Hampton Avenue	12.57	12.57	--	--	--	--	0.00	12.57	--
	Total	--	--	--	--	60.06	--	--	--	--	11.79	71.85	--

Subwatershed		Hydraulic Structures on That Portion of the Stream for Which Flood Stage Profiles Were Developed																			
		Bridges and Culverts[c]			Dams			Drop Structures			All Structures			Channel Modifications							
														Minor		Major		Conduit		Total	
Number	Name	Hydraulically Significant	Hydraulically Insignificant	Total	Hydraulically Significant	Hydraulically Insignificant	Total	Hydraulically Significant	Hydraulically Insignificant	Total	Hydraulically Significant	Hydraulically Insignificant	Total	Miles	Percent	Miles	Percent	Miles	Percent	Miles	Percent
1	North Branch of the Menomonee River	4	1	5	0	0	0	0	0	0	4	1	5	0.71	38.8	--	--	--	--	0.71	38.8
2	West Branch of the Menomonee River	6	1	7	0	0	0	0	0	0	6	1	7	1.63	79.5	--	--	--	--	1.63	79.5
3	Willow Creek	3	0	3	0	0	0	0	0	0	3	0	3	1.65	100.0	--	--	--	--	1.65	100.0
4	Nor-X-Way Channel	10	2	12	0	1	1	0	0	0	10	3	13	1.06	51.0	1.02	49.0	--	--	2.08	100.0
5	Lilly Creek	12	4	16	0	0	0	0	0	0	12	4	16	3.29	100.0	--	--	--	--	3.29	100.0
6	Butler Ditch	3	2	5	0	0	0	0	0	0	3	2	5	0.33	13.9	--	--	--	--	0.33	13.9
7	Upper Menomonee River	32	13	45	1	0	1	1	0	1	34	13	47	5.58	33.1	1.11	6.59	--	--	6.69	39.7
8	Little Menomonee Creek	3	5	8	0	0	0	0	0	0	3	5	8	0.45	20.0	--	--	--	--	0.45	20.0
9	Little Menomonee River	18	10	28	0	0	0	0	0	0	18	10	28	9.31	91.5	0.31	3.05	--	--	9.62	94.6
10	Dousman Ditch	3	1	4	0	0	0	0	0	0	3	1	4	0.64	100.0	--	--	--	--	0.64	100.0
11	South Branch Underwood Creek	4	0	4	0	0	0	0	0	0	4	0	4	--	--	1.08	100.0	--	--	1.08	100.0
12	Underwood Creek	30	12	42	0	2	2	7	0	7	37	14	51	2.73	36.5	3.32	44.4	0.12	1.61	6.17	82.5
13	Honey Creek	21	1	22	0	1	1	10	0	10	32	1	33	0.41	5.43	4.20	55.6	2.42	32.1	7.03	93.1
14	Lower Menomonee River	21	27	48	1	0	1	0	0	0	22	27	49	2.10	16.7	4.75	37.8	--	--	6.85	54.5
	Total	170	79	249	2	4	6	18	0	18	190	83	273	29.89	41.6	15.79	22.0	2.54	3.54	48.22	67.1

[a] As shown on U. S. Geological Survey Quadrangle Maps.

[b] Applicable to that portion of the stream for which flood stage profiles were developed.

[c] Includes existing or former fords.

Source: SEWRPC.

Table 30

SELECTED HYDROLOGIC DATA FOR THE MENOMONEE RIVER WATERSHED BY SUBWATERSHED: 1970

Subwatershed[a] Number	Subwatershed[a] Name	Area: Acres (1970)	Area: Square Miles (1970)	Area: Percent of Watershed	Total Area Tributary to Downstream: Acres	Total Area Tributary to Downstream: Square Mile	Subbasins: Number	Subbasins: Largest (Square Miles)	Subbasins: Smallest (Square Miles)	Subbasins: Mean Area (Square Miles)
1	North Branch-Menomonee River	2,729.06	4.26	3.14	2,729.06	4.26	6	0.867	0.436	0.618
2	West Branch-Menomonee River	2,849.17	4.45	3.28	2,849.17	4.45	10	0.995	0.099	0.462
3	Willow Creek	4,055.58	6.34	4.67	4,055.58	6.34	8	1.476	0.336	0.779
4	Nor-X-Way Channel	3,364.40	5.26	3.88	3,364.40	3.88	11	0.944	0.099	0.467
5	Lilly Creek	3,933.17	6.15	4.53	3,933.17	6.15	11	0.992	0.337	0.550
6	Butler Ditch	3,628.72	5.67	4.18	3,628.72	5.67	14	0.719	0.204	0.385
7	Little Menomonee Creek	2,120.39	3.31	2.44	2,120.39	3.31	7	0.655	0.259	0.471
8	Little Menomonee River	11,448.13	17.89	13.19	13,568.52	21.20	31	1.291	0.062	0.601
9	Upper Menomonee River	18,631.79	29.11	21.47	39,191.89	61.24	47	1.632	0.067	0.634
10	Dousman Ditch	2,303.73	3.60	2.65	2,303.73	3.60	9	0.665	0.190	0.416
11	South Branch-Underwood Creek[b]	3,187.64	4.98	3.67	3,187.64	4.98	14	0.661	0.100	0.368
12	Underwood Creek	7,205.73	11.26	8.30	12,697.10	19.84	19	1.221	0.069	0.586
13	Honey Creek[c]	6,603.24	10.32	7.61	6,603.24	10.32	19	1.055	0.067	0.565
14	Lower Menomonee River[d]	14,741.10	23.03	16.99	86,801.85	135.63	38	1.588	0.110	0.605
	Total	86,801.85	135.63	100.00	--	--	244	--	--	--

Subwatershed Number	Hydrologic Soil Groups A: Square Mile	A: Percent of Sub-watershed	B: Square Mile	B: Percent of Sub-watershed	C: Square Mile	C: Percent of Sub-watershed	D: Square Mile	D: Percent of Sub-watershed	Other Soil Groups Made Land: Square Mile	Made Land: Percent of Sub-watershed	Other: Square Mile	Other: Percent of Sub-watershed	Impervious: Square Mile	Impervious: Percent of Sub-watershed	Unclassified: Square Mile	Unclassified: Percent of Sub-watershed
1	0.00	0.00	1.84	43.22	1.07	25.04	1.35	31.61	0.00	0.00	0.00[e]	0.13	0.00	0.00	0.00	0.00
2	0.00	0.00	2.93	65.96	0.47	10.45	0.97	21.75	0.01	0.17	0.07	1.67	0.00	0.00	0.00	0.00
3	0.01	0.18	3.22	50.84	1.52	23.91	1.43	22.54	0.04	0.66	0.09	1.44	0.03	0.43	0.00	0.00
4	0.00	0.00	0.83	15.74	3.54	67.36	0.36	6.88	0.53	9.99	0.00[e]	0.03	0.00	0.00	0.00	0.00
5	0.00	0.00	0.06	0.97	4.94	80.32	0.91	14.79	0.24	3.84	0.00	0.00	0.00[e]	0.08	0.00	0.00
6	0.00	0.00	0.03	0.52	4.65	82.02	0.74	13.08	0.14	2.54	0.11	1.84	0.00	0.00	0.00	0.00
7	0.00	0.00	0.45	13.72	2.29	69.26	0.55	16.54	0.00	0.00	0.02	0.48	0.00	0.00	0.00	0.00
8	0.00	0.00	0.92	5.13	12.25	68.45	2.77	15.49	1.62	9.07	0.17	0.98	0.16	0.88	0.00	0.00
9	0.00	0.00	4.32	14.83	16.30	55.98	6.05	20.79	1.96	6.75	0.29	1.01	0.19	0.64	0.00	0.00
10	0.00	0.00	0.31	8.64	1.76	48.89	1.31	36.51	0.09	2.52	0.00	0.00	0.13	3.44	0.00	0.00
11	0.00	0.00	0.31	6.29	2.38	47.76	0.64	12.91	1.13	22.75	0.19	3.82	0.12	2.26	0.21	4.21
12	0.00	0.00	0.51	4.56	7.60	67.49	1.55	13.80	1.39	12.32	0.12	1.09	0.09	0.74	0.00	0.00
13	0.00	0.00	0.00	0.00	2.88	27.89	0.26	2.56	0.29	2.84	0.01	0.06	0.02	0.20	6.86	66.45
14	0.00	0.00	0.14	0.63	5.24	22.77	0.40	1.74	1.54	6.68	0.03	0.11	0.35	1.51	15.33	66.56
Total	0.01	--	15.88	--	66.88	--	19.29	--	8.98	--	1.10	--	1.09	--	22.40	--

Subwatershed[a] Number	Subwatershed[a] Name	Land Use, Urban: Residential Acres	Residential Percent of Sub-watershed	Retail and Service Acres	Retail and Service Percent of Sub-watershed	Wholesale and Storage Acres	Wholesale and Storage Percent of Sub-watershed	Manufacturing Acres	Manufacturing Percent of Sub-watershed	Transportation, Communication, and Utility Facilities Acres	Transportation, Communication, and Utility Facilities Percent of Sub-watershed
1	North Branch-Menomonee River	76.33	2.80	0.73	0.03	3.19	0.12	0.00	0.00	111.78	4.10
2	West Branch-Menomonee River	135.94	4.77	4.78	0.17	0.00	0.00	63.94	2.24	213.70	7.50
3	Willow Creek	532.21	13.12	4.57	0.11	0.91	0.02	52.21	1.29	252.98	6.24
4	Nor-X-Way Channel	301.40	8.96	28.84	0.86	9.29	0.28	32.30	0.96	288.47	8.57
5	Lilly Creek	1,186.48	30.16	14.93	0.40	38.71	0.98	16.26	0.41	306.46	7.79
6	Butler Ditch	1,907.86	52.57	61.96	1.71	0.00	0.00	11.68	0.32	420.06	11.58
7	Little Menomonee Creek	179.85	8.48	2.25	0.11	0.00	0.00	50.46	2.38	67.27	3.17
8	Little Menomonee River	1,896.56	16.57	76.45	0.67	164.10	1.43	48.68	0.43	1,415.52	12.36
9	Upper Menomonee River	2,599.95	13.95	175.62	0.94	116.95	0.63	224.24	1.20	1,736.21	9.32
10	Dousman Ditch	895.55	38.87	58.89	2.56	3.08	0.13	0.00	0.00	280.45	12.17
11	South Branch-Underwood Creek[b]	1,161.70	36.43	63.02	1.98	82.26	2.58	78.08	2.45	835.38	26.21
12	Underwood Creek	3,013.68	41.81	94.88	1.32	37.15	0.52	107.37	1.49	1,421.31	19.72
13	Honey Creek[c]	2,966.33	44.92	141.21	2.14	74.99	1.14	103.38	1.57	1,795.32	27.19
14	Lower Menomonee River[d]	4,837.86	32.82	406.82	2.76	459.95	3.12	662.35	4.49	5,072.00	34.41
	Total	21,691.70	--	1,134.95	--	990.58	--	1,450.95	--	14,216.91	--

Subwatershed Number	Urban: Government and Institutional Acres	Government and Institutional Percent of Sub-watershed	Park and Recreation Acres	Park and Recreation Percent of Sub-watershed	Total Urban Acres	Total Urban Percent of Sub-watershed	Rural: Agriculture and Related Acres	Agriculture and Related Percent of Sub-watershed	Open Lands, Swamps, and Water Acres	Open Lands, Swamps, and Water Percent of Sub-watershed	Total Rural Acres	Total Rural Percent of Sub-watershed
1	0.02	0.00	2.59	0.09	194.64	7.13	2,176.97	79.76	357.45	13.10	2,534.42	92.87
2	6.77	0.24	1.10	0.04	426.23	14.96	2,156.75	75.70	266.19	9.34	2,422.94	85.04
3	15.87	0.39	14.03	0.35	872.78	21.52	2,490.31	61.41	692.49	17.07	3,182.80	78.48
4	7.56	0.22	1.19	0.04	669.05	19.89	2,218.62	65.94	476.73	14.17	2,695.35	80.11
5	17.38	0.44	78.30	1.99	1,658.52	42.17	1,899.99	48.30	374.66	9.53	2,274.65	57.83
6	122.92	3.39	6.13	0.17	2,530.61	69.74	735.64	20.27	362.47	9.99	1,098.11	30.26
7	10.87	0.51	0.00	0.00	310.70	14.65	1,537.61	72.52	272.08	12.83	1,809.69	85.35
8	273.76	2.39	568.12	4.96	4,443.19	38.81	5,447.89	47.59	1,557.05	13.60	7,004.94	61.19
9	283.24	1.52	741.22	3.98	5,877.43	31.55	9,173.46	49.24	3,580.90	19.22	12,754.36	68.45
10	141.81	6.16	19.95	0.87	1,399.73	60.76	434.17	18.85	469.83	20.39	904.00	39.24
11	55.50	1.74	377.99	11.86	2,653.93	83.26	74.19	2.33	459.52	14.42	533.71	16.74
12	449.72	6.24	517.07	7.18	5,641.18	78.29	376.67	5.23	1,187.88	16.49	1,564.55	21.71
13	461.76	6.99	428.81	6.49	5,971.80	90.44	78.86	1.19	552.58	8.37	631.44	9.56
14	1,365.24	9.26	1,058.09	7.18	13,862.31	94.04	66.19	0.45	812.60	5.51	878.79	5.96
Total	3,212.42	--	3,814.59	--	46,512.10	53.58	28,867.32	--	11,422.43	--	40,289.75	46.42

[a] *With the exception of subbasin areas, data presented in this table was determined by means of approximating the subwatersheds by U. S. Public Land survey quarter sections. The actual measured total watershed area is 137.23 square miles, whereas the watershed area as approximated by 538 quarter sections is 135.63 square miles.*

[b] *Soils data are available for only 4.77 square miles or 95.79 percent of the South Branch Underwood Creek subwatershed.*

[c] *Soils data are available for only 3.46 square miles or 33.55 percent of the Honey Creek subwatershed.*

[d] *Soils data are available for only 7.70 square miles or 33.44 percent of the Lower Menomonee River subwatershed.*

[e] *Area is less than 0.01 square mile.*

Source: SEWRPC.

ties; and placement at the points where U. S. Public Land Survey section and quarter section lines intersect the streams in order to facilitate the preparation of large-scale flood hazard maps showing the numerical value of the regulatory flood stages related to real property boundary lines.

With respect to orientation, the floodland cross-sections were positioned so as to be approximately perpendicular to the main flow of the stream during flood flow conditions. The terminal points of the cross-section were established at sufficient distance laterally from the stream so as to be well outside of the anticipated 100-year recurrence interval floodland limits.

Roughness Coefficient: The Manning roughness coefficient is a relative measure of the ability of a channel and its floodplain to convey flow. The discharge that can be conveyed in a given reach of channel at a specified channel slope and water stage is inversely proportional to the Manning roughness coefficient; that is, the carrying capacity diminishes as the value of the roughness coefficient increases.

Roughness coefficients are a function of several factors including the kind of material—such as earth, gravel, and rock—forming the channel and attendant natural floodplain; the kind and density of vegetation—for example, rooted aquatic plants in the channel, and grass, agricultural crops, brush, and trees on the adjacent natural floodplain; and the sinuosity or degree of meandering of the channel. Floodland Manning roughness coefficients were assigned on the basis of field examination of the 71.85 miles of stream in the Menomonee River watershed for which detailed flood hazard information was to be developed. Values were estimated on the basis of the various factors summarized in Table 31, assuming summer or growing season conditions. These data which, in a particular reach, were developed separately for the channel and each attendant natural floodplain were input to the hydrologic-hydraulic model used in the watershed planning program.

Channel Modification: Channel modifications—or channelization as it is commonly termed—usually include one or more of the following changes to the natural stream channel: straightening, channel deepening and thereby lowering of the channel profile, channel widening, placement of a concrete invert and sidewalls, and reconstruction of selected bridges and culverts. At times the natural channel may be relocated or completely enclosed in a conduit. These modifications to the natural channel generally yield a lower, hydraulically more efficient waterway, that results in significantly lower flood stages within the channelized reach. While channelization can be an effective means of reducing flood damages, it may entail high aesthetic and ecological costs. Moreover, because of the increased streamflow velocities resulting from channelization, channel modifications tend to increase downstream peak flood discharges and stages, and, therefore, flood problems.

In contrast to most of the other watersheds in the Region, a rather large portion of the stream system of the Menomonee River watershed has been intentionally modified for flood control purposes. Of the 71.85 miles of stream system in the watershed selected for development of detailed flood hazard data, approximately 48 miles, or 67 percent, are known to have undergone some type of man-made channel modification.

Map 40 shows the lineal extent and the nature of known man-made channel modifications within the Menomonee River watershed on the portion of stream system selected for development of detailed flood hazard data. The following three types of channelization were defined, and are shown on Map 40, to illustrate the extent to which the original stream channel system has been altered:

1. Minor channelization: Localized clearing and widening with scattered straightening. Little or no concrete or masonry on either the channel bottom or side slopes. Channel modifications not readily apparent to the casual observer. Examples of minor channelization include agricultural improvements along the Little Menomonee River in northwestern Milwaukee County and the urban area modifications evident along Underwood Creek in the City of Brookfield upstream of the Village of Elm Grove and the Honey Creek segment downstream of Wisconsin Avenue in the City of Wauwatosa.

2. Major channelization: Continuous and extensive deepening, widening and straightening, possibly with major relocations. Extensive application of concrete or masonry to channel bottom or side walls. Channel modifications are readily apparent to the casual observer. Major channelization is exemplified by that portion of Underwood Creek lying within the City of Wauwatosa and by the main stem of the Menomonee River downstream of Hawley Road in the City of Milwaukee.

3. Conduit: The original natural channel has been completely enclosed in a conduit. The principal example of this form of channel modification is the 2.3 mile long reach of Honey Creek lying within the Cities of West Allis and Milwaukee.

The above classification of channel modifications, particularly the minor and major channelization categories, is intended to describe the degree to which the channel proper has been altered and is not, therefore, necessarily an indicator of the aesthetic impact of the channelization. Compare, for example, the 0.75 mile portion of Underwood Creek downstream of USH 45 and the 0.31 mile segment of Honey Creek bounded by Blue Mound Road on the upstream end and Wisconsin Avenue on the downstream end. While both these urban area reaches underwent major channelization, the Honey Creek reach exhibits a significantly higher aesthetic quality primarily because of the contiguous open space, wide relative to the channel, that lies on both sides of

Figure 35

CHANNEL BOTTOM PROFILES FOR THE MENOMONEE RIVER AND SELECTED TRIBUTARIES

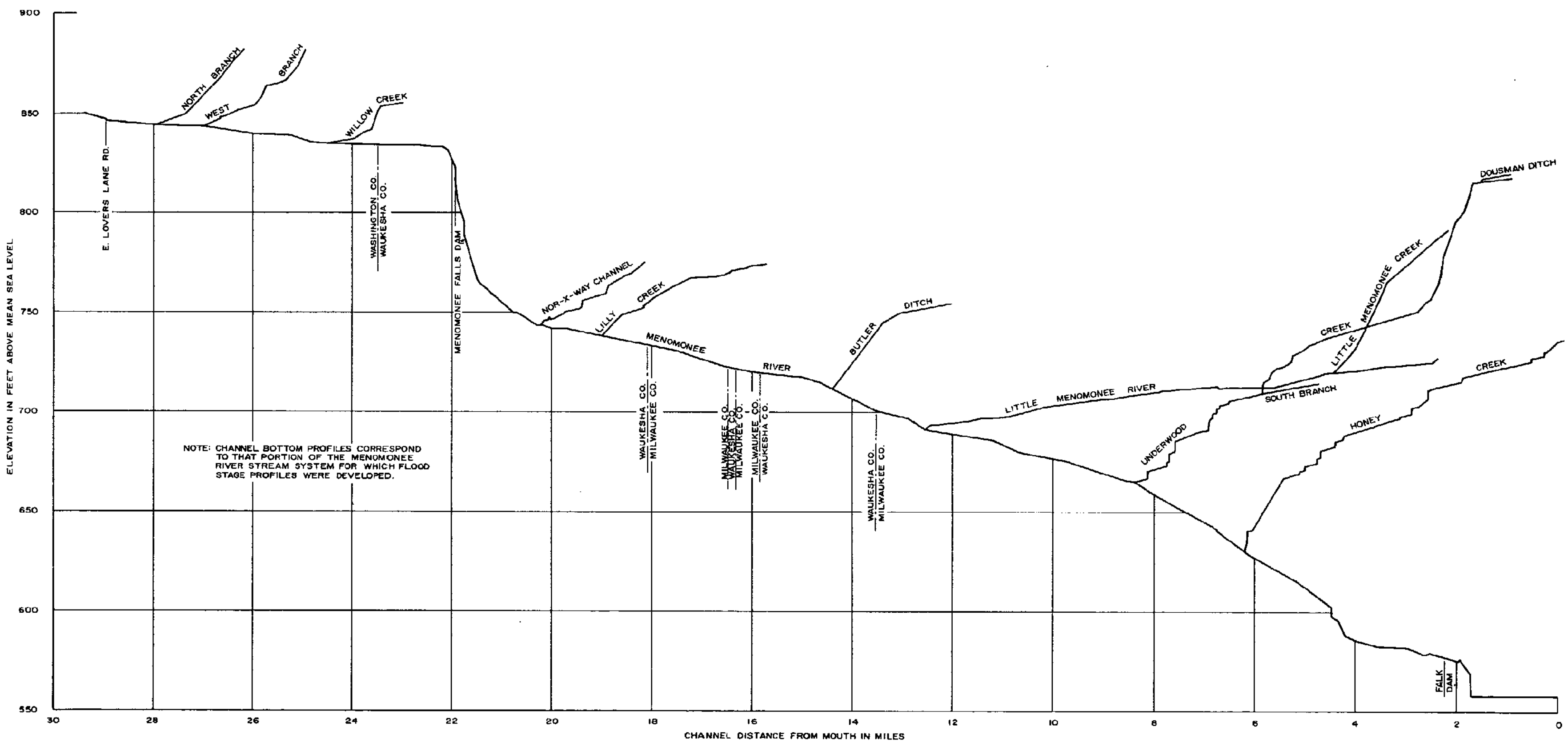
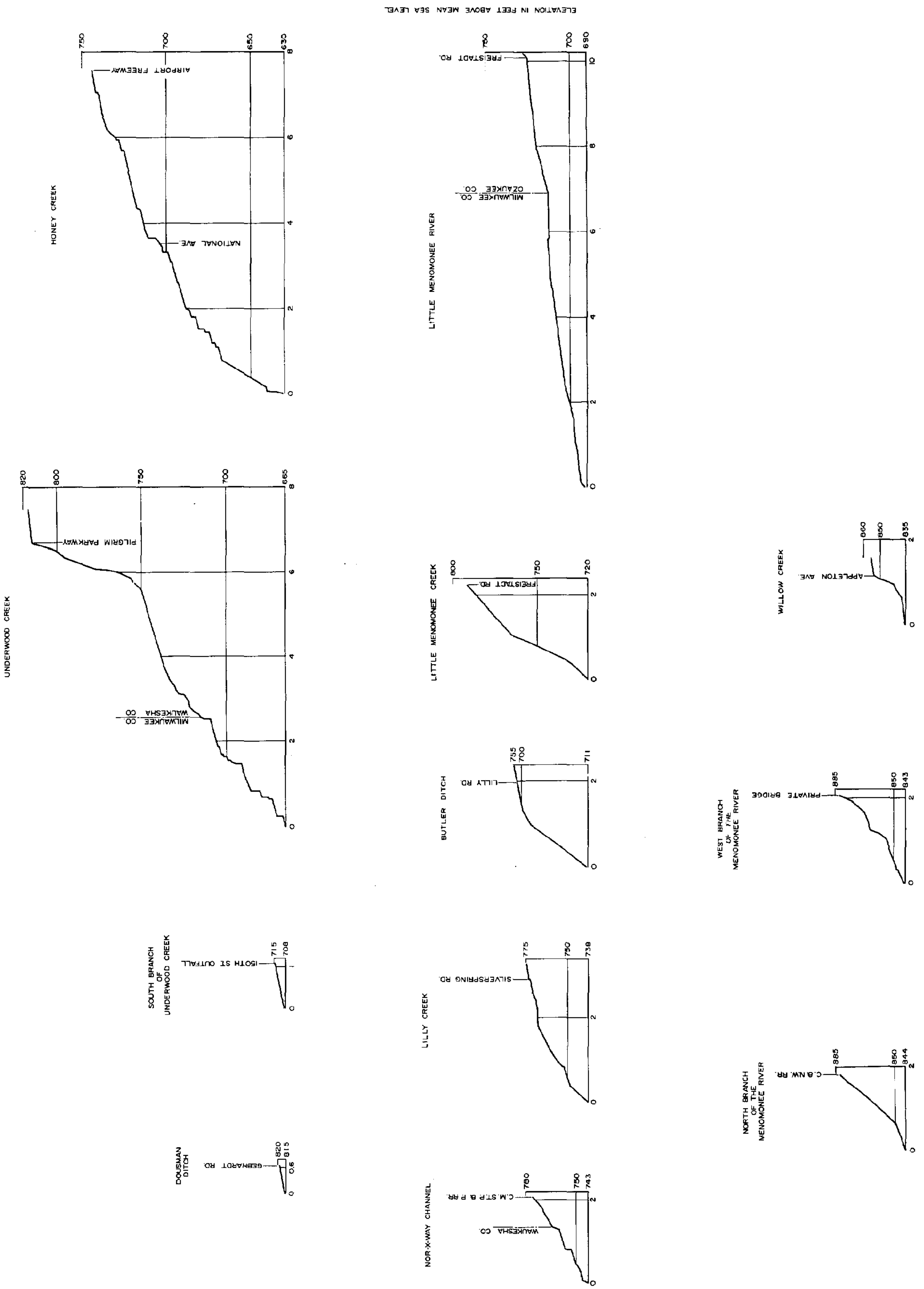


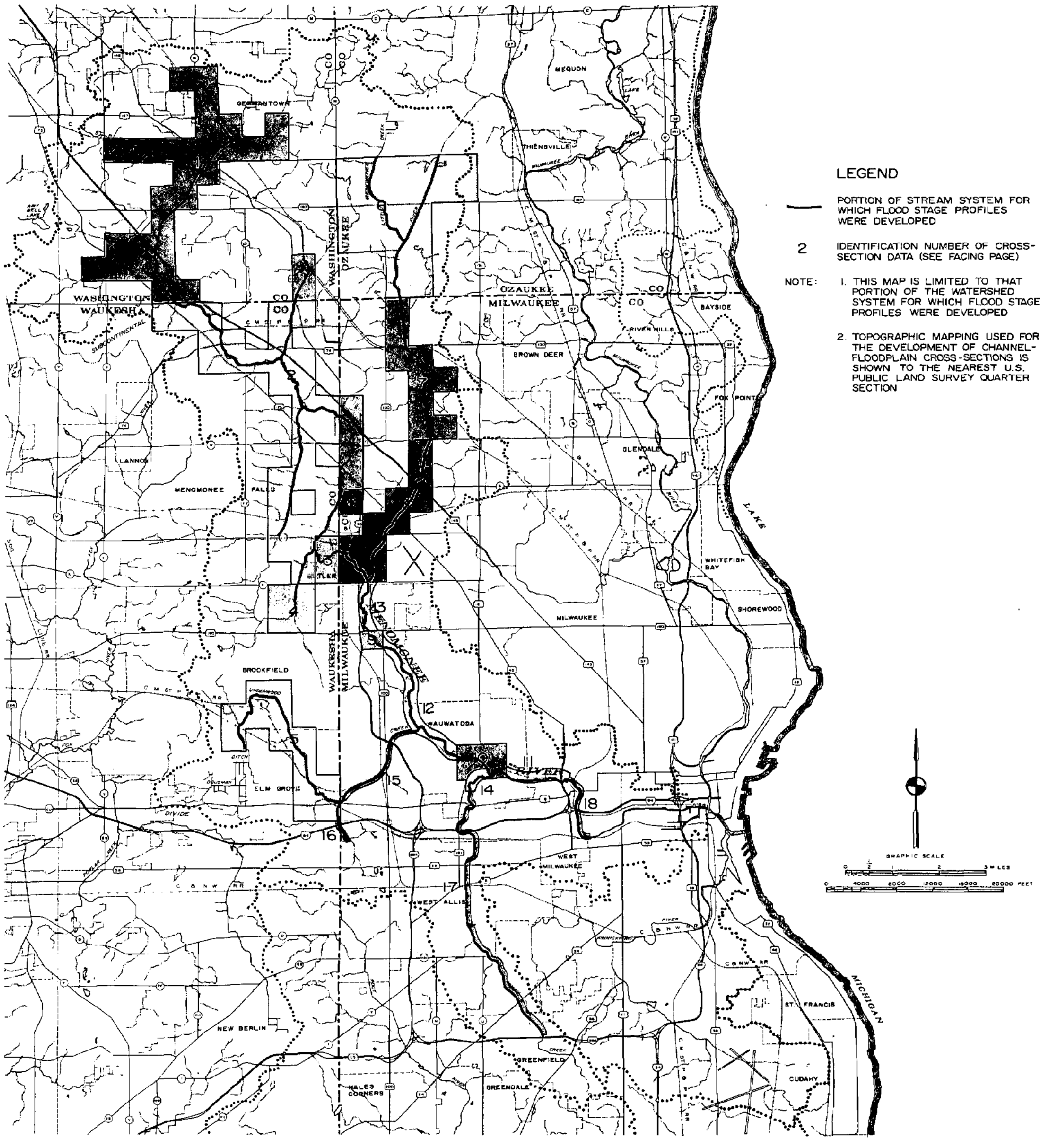
Figure 35 (continued)



Source: SEWRPC.

Map 39

SOURCES OF CROSS-SECTION DATA FOR CHANNEL FLOODPLAIN IN THE MENOMONEE RIVER WATERSHED



Approximately 933 floodland cross sections at an average spacing of 500 feet were developed for the 71.85 miles of stream modeled under the Menomonee River watershed study. The floodland cross sections were developed from the several sources shown above which include: large scale topographic maps of the riverine areas, photogrammetric cross sections of the riverine areas, and channel modification plans. Floodland cross sections are used to determine the hydraulic characteristics of the stream channel and floodplains, which characteristics determine flood stage and the lateral extent of inundation for a given flood discharge.

Source: SEWRPC.

Map 39 (continued)

Large-Scale Topographic Mapping

Identification Number on Map 39	Civil Division		Scale	Contour Interval (feet)	Agency or Community For Which Mapping Was Originally Prepared	Date of Photography or Field Work	Date of Map Preparation
	County	City, Village, or Town					
1	Washington	Village of Germantown	1" = 100'	2	Village of Germantown	1964	1964
2	Waukesha	Village of Menomonee Falls	1" = 200'	2	Village of Menomonee Falls	1966	1967
3	Waukesha	Village of Butler	1" = 200'	2	Wisconsin Division of Highways	1966	1967
4	Waukesha	City of Brookfield	1" = 200'	5	Waukesha County	1956	1956
5	Waukesha	City of Brookfield	1" = 200'	2-4	Southeastern Wisconsin Regional Planning Commission	1972	1974
6	Ozaukee	City of Mequon	1" = 200'	5	City of Mequon	1960	1960
7	Milwaukee	City of Milwaukee	1" = 100'	2	City of Milwaukee	1962	1967
8	Milwaukee	City of Milwaukee	1" = 100'	2	City of Milwaukee	1956	1957
9	Milwaukee	City of Wauwatosa	1" = 100'	1	Milwaukee County Park Commission	1966	1966
10	Milwaukee	City of Wauwatosa	1" = 100' reduced to 1" = 200'	2	City of Wauwatosa	1954	1960

SEWRPC Photogrametric Cross Sections

Identification Number on Map 39	Stream Reach	Scale	River Mile		Date	
			From	To	Photography	Completion
11	Menomonee River	1" = 200'	4.47	5.94	1972	1972
12	Menomonee River	1" = 200'	7.15	10.65	1972	1972
13	Menomonee River	1" = 200'	11.25	12.50	1972	1972
14	Honey Creek	1" = 200'	0.30	0.89	1972	1972

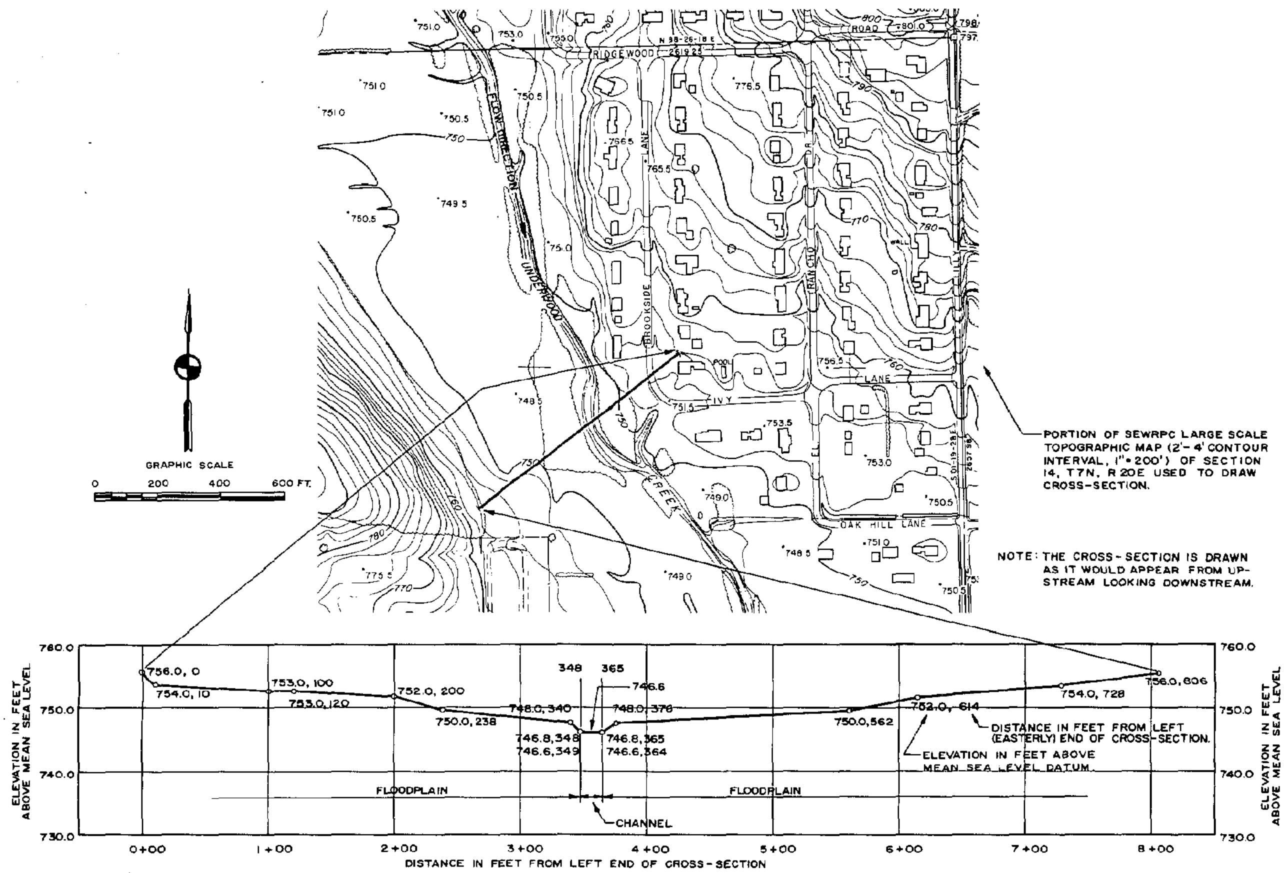
Milwaukee Metropolitan Sewerage Commission Channel Improvements Contract Drawings

Identification Number on Map 39	Stream Reach	Contract Number	River Mile		Date	
			From	To	Awarded	Completed
15	Underwood Creek	146	0.00	0.81	5-26-64	5-11-65
		211	0.81	1.54	9-28-67	8-01-69
		220	1.54	2.54	9-28-71	10-31-73
16	South Branch Underwood Creek	220	0.00	0.05	9-28-71	10-31-73
		225	0.05	1.06	4-01-68	11-30-70
		235	1.06	1.08	11-04-69	11-30-70
17	Honey Creek	179	0.91	1.99	12-05-63	1-07-65
		194	1.99	3.08	1-08-64	2-02-65
		203	3.08	3.45	5-10-65	7-20-66
		204	3.45	3.80	7-22-65	9-19-66
		208	3.80	4.32	2-10-65	2-03-67
		209	4.32	5.27	12-12-66	9-07-67
		795	5.27	5.96	4-01-68	8-31-69
		635	5.96	6.54	6-27-60	11-21-60
		236	6.54	7.53	9-28-71	10-01-73
18	Menomonee River	723	3.00	3.56	11-21-61	7-05-62
		727	3.56	4.47	9-25-65	8-01-68

Source: SEWRPC.

Figure 36

TYPICAL CROSS-SECTION OF CHANNEL FLOODPLAIN IN THE MENOMONEE RIVER WATERSHED



Source: SEWRPC.

the channel. While the Underwood Creek channelization occupies most of the available space between abutting development, the wide and landscaped Milwaukee County Parkway along Honey Creek has the effect of ameliorating the potentially negative aesthetic impact of the channelization of the creek.

In accordance with the above definitions, the 71.85 miles of the watershed stream system selected for hydrologic-hydraulic simulation, contain, as shown in Table 29, 29.9 miles of minor channelization, 15.8 miles of major channelization, and 2.5 miles of conduit, for a total of 48.2 miles of channel modifications. This value, which encompasses about 67 percent of the stream system selected for development of detailed flood hazard data, is necessarily a minimum or lower limit inasmuch as it is difficult to identify with certainty all of those stream reaches in the minor channelization category.

As is evident on Map 40, channel modifications, especially those in the major channelization and in the conduit categories, are concentrated in the older urban areas of the Menomonee River watershed in general and in Milwaukee County in particular. For example, although Milwaukee County encompasses only 33.1 miles, or about 46 percent of the selected stream system, it contains 24.7 miles, or about 51 percent of the channel modifications existing in the watershed. Furthermore, virtually all of the channel modifications in the major channelization and conduit categories within the watershed are contained within Milwaukee County. The concentration of channel modifications in the urban area in general, and in Milwaukee County in particular, indicates that mitigation of flood problems to riverine area urban development has been the primary motivation for channel modifications in the Menomonee River watershed.

With respect to downstream riverine areas, the potential hydraulic effect of channelization is very similar to that of floodplain fill and development in that channelization reduces the floodwater storage capability of the modified reach, thereby generally giving rise to downstream flood hydrographs that have, relative to pre-channelization conditions, shorter bases and higher peaks. It is possible, however, depending on the relative position of the

Table 31

MANNING ROUGHNESS COEFFICIENTS APPLIED TO THE
CHANNEL AND FLOODPLAINS OF THE MENOMONEE RIVER WATERSHED

Channel			
Condition			Roughness Coefficient Component[a]
Material involved	Earth	n_1	0.020
	Rock cut		0.025
	Fine gravel		0.024
	Coarse gravel		0.028
Degree of irregularity	Smooth	n_2	0.000
	Minor		0.005
	Moderate		0.010
	Severe		0.020
Relative effect of obstructions	Negligible	n_3	0.000
	Minor		0.010-0.015
	Appreciable		0.020-0.030
	Severe		0.040-0.060
Vegetation	Low	n_4	0.005-0.010
	Medium		0.010-0.025
	High		0.025-0.050
	Very high		0.050-0.100
Degree of meandering	Minor	k	1.000
	Appreciable		1.150
	Severe		1.300

Floodplain				
Condition		Roughness Coefficient		
		Minimum	Normal	Maximum
Pasture	Short grass	0.025	0.030	0.035
	High grass	0.030	0.035	0.050
Cultivated Areas	No Crop	0.020	0.030	0.040
	Mature row crops	0.025	0.035	0.045
	Mature field crops	0.030	0.040	0.050
Brush	Scattered brush, heavy weeds	0.035	0.050	0.070
	Light brush and trees, in winter	0.035	0.050	0.060
	Light brush and trees, in summer	0.040	0.060	0.080
	Medium to dense brush, in winter	0.045	0.070	0.110
	Medium to dense brush, in summer	0.070	0.100	0.160
Trees	Dense willows, summer, straight	0.110	0.150	0.200
	Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
	Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
	Heavy stand of timber a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
	Same as above, but with flood stage reaching branches	0.100	0.120	0.160

[a] *The composite Manning roughness coefficient for a channel reach = $k\ (n_1 + n_2 + n_3 + n_4)$.*

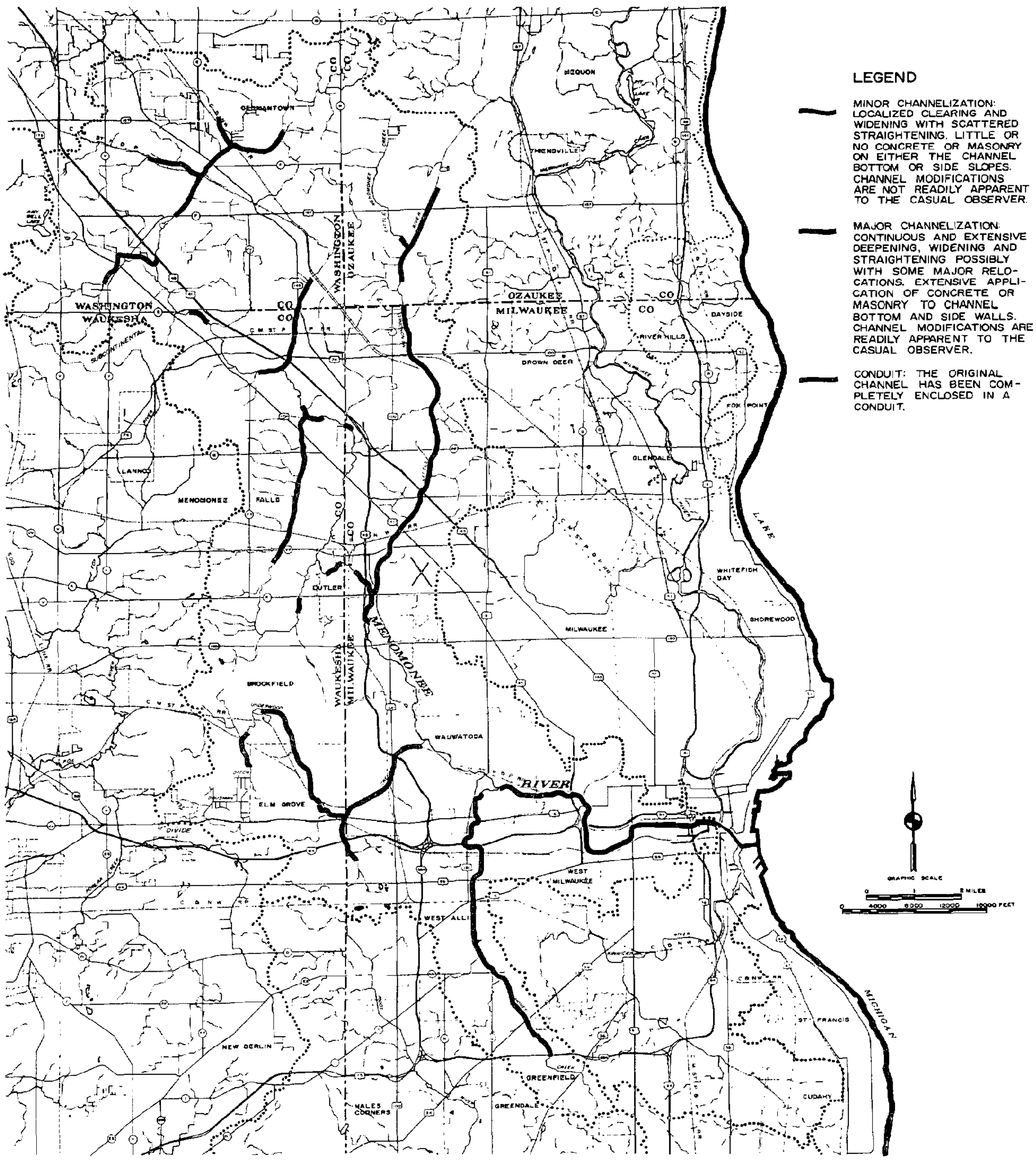
Source: Chow, V. T., Open Channel Hydraulics, Chapter 5, McGraw-Hill Book Co., 1959.

channelized reach or reaches in the watershed stream system, for channelization to result in reduced downstream discharges. For example, channelization in the lower reaches of a watershed may provide for the rapid removal of lower watershed runoff from that portion of the watershed prior to the arrival of middle and upper watershed drainage thereby reducing lower watershed discharges and stages.

The effects of channel improvement projects are the reverse of the effect of other structural flood control measures, such as reservoirs, which are designed to impede flow, decrease velocity, and cause backwater effects. Channel improvements accelerate flow, increase velocity, and reduce upstream backwater effects. Control structures tend to prolong the base time of surface runoff and decrease peak discharges in the downstream direction,

Map 40

CHANNEL MODIFICATIONS IN THE MENOMONEE RIVER WATERSHED



As is evident from the map above, channel modifications, especially those consisting of major channelization and of the installation of conduits, are concentrated in the older urban areas of the Menomonee River watershed in general and in Milwaukee County in particular. In all, a total of 48.2 miles of the watershed stream system have been subjected to some form of channel modification.

Source: SEWRPC.

while channel improvements have the effect of decreasing base time and increasing stage and the peak flow rate downstream from the improvement.

It is apparent, therefore, that haphazard and uncoordinated channel modification may cause adverse effects elsewhere in a watershed, resulting in little or no overall benefits on the surface water problems of a watershed. This possibility points to the need for proper water management practices based upon a comprehensive watershed plan. In recognition of the need to evaluate the potential downstream effect of channelization proposals within the Menomonee River watershed, one of the standards supporting the adopted water control facility development objectives, as set forth in Chapter II, Volume 2, "Watershed Development Objectives, Principles and Standards" requires the explicit determination of the downstream impact of proposed channel modifications.

Because adequate historic data is lacking, it is extremely difficult to make a meaningful quantitative evaluation, based solely on such data, of the overall effect which existing channel improvement projects have had on the flow regimen of the stream system of the whole watershed. Because of the large amount of natural storage that still exists within the headwater segments of the channel system of the watershed, it is reasonable to assume, however, that extensive additional channelization in the upper reaches of the watershed could seriously aggravate existing flood problems in the lower portion of the watershed.

Bridges and Culverts: Depending on the size of the waterway opening and the characteristics of the approaches, bridges and culverts can be important elements in the hydraulics of a watershed, particularly with respect to localized effects. The construction caused by an inadequately designed bridge or culvert can, under flood discharge conditions, result in a large backwater effect and thereby create upstream flood stages that are significantly higher, and an upstream floodland that is significantly larger, than would exist in the absence of the bridge or culvert.

As of the end of 1974, the 71.85 lineal miles of Menomonee River waterstream system selected for hydrologic-hydraulic modeling were crossed, as shown on Map 41, by 249 bridges and culverts having an average spacing of 0.3 mile. The heavy concentration of bridges and culverts in the stream system reflects the urban nature of the watershed. While the hydraulic submodel of the hydrologic-hydraulic simulation model as described in Chapter VIII, "Water Resource Simulation Model," has the capability of accommodating any number or type of bridge or culvert, the cost of the field surveys necessary to acquire the input data for the submodel required that a determination be made, based on a field reconnaisance, of the hydraulic significance of each bridge or culvert in order significantly to reduce the number of structures for which complete physical descriptions would have to be obtained.

A bridge or culvert was defined as being hydraulically significant if field inspection suggested that the structure might influence flood stages by 0.5 feet or more for the 10- through 100-year recurrence interval flood discharges. In examining each bridge or culvert to evaluate its potential hydraulic significance, the structure was considered to consist of the approaches as well as structural components such as abutments, piers, and deck in the immediate vicinity of the waterway opening.

One category of hydraulically insignificant bridges and culverts consists of those having a relatively small superstructure relative to the combined width of the channel and its natural floodplain. Such structures typically have approaches that do not rise significantly above the floodplain while the portion of the structure in the immediate vicinity of the channel simply spans the channel. Pedestrian crossings and private roadway bridges and culverts comprise most of the bridges and culverts in this category of hydraulically insignificant structures. An example of this type of hydraulically insignificant structure is, as shown in Figure 37, a pedestrian bridge over the Menomonee River in the Village of Menomonee Falls.

The second category of hydraulically insignificant bridges and culverts consists of those that, while major structures in the sense of carrying railroads and public streets and highways and particularly arterial streets and highways across the floodland, nevertheless they are elevated on piers well above the channel and the floodplain, they utilize little or no fill for the approaches, and therefore they offer little impedance to flow during even major flood events. An example of this type of hydraulically insignificant structure is, as shown in Figure 37, the East-West Freeway (IH 94) bridge over the Menomonee River in the City of Milwaukee.

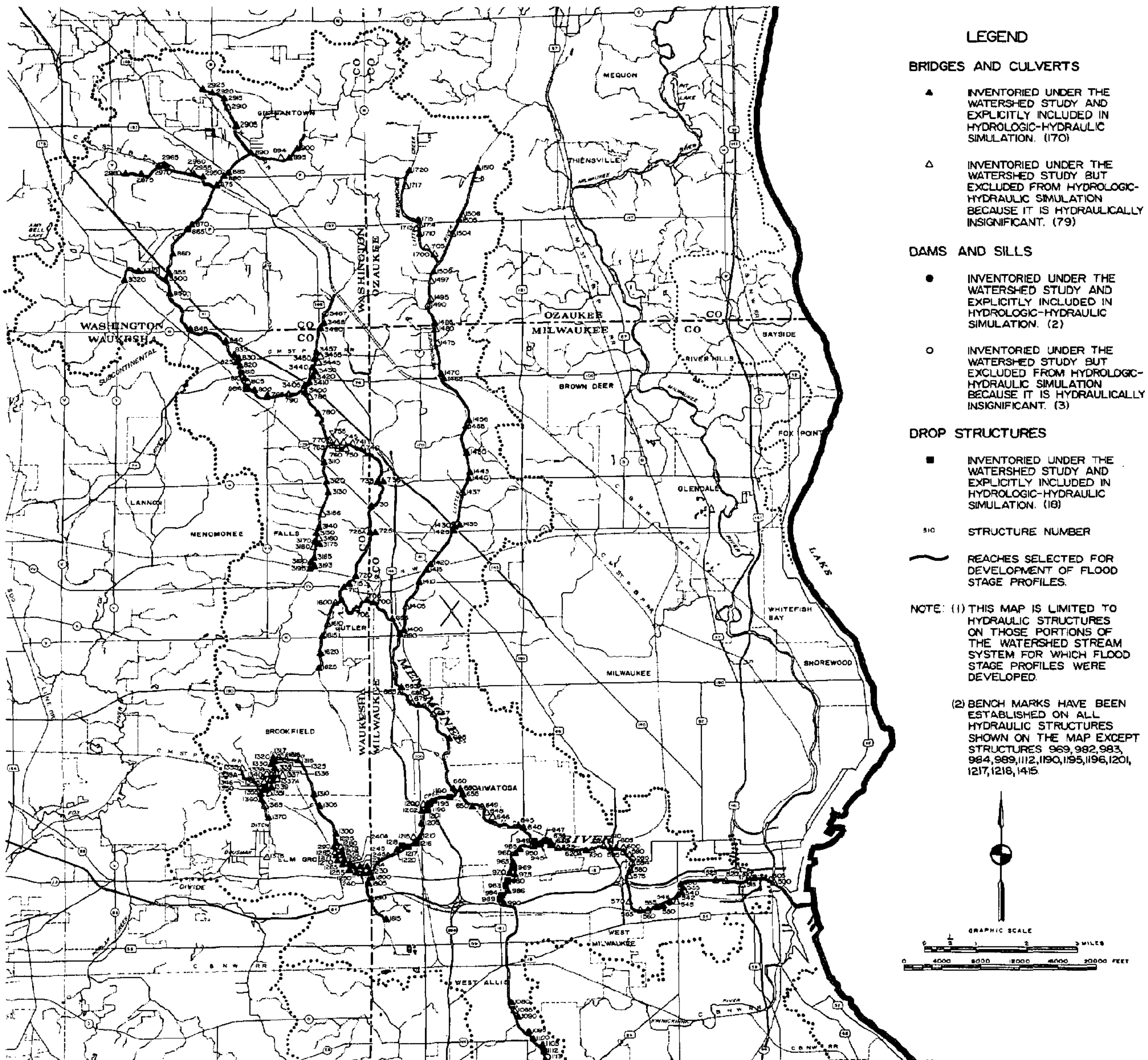
Hydraulically significant bridges and culverts generally are characterized by relatively small waterway openings in combination with approaches that are constructed well above the elevation of the floodplain. Such structures function as dams and have the potential for obstructing streamflow during major flood events. As shown in Figure 38, examples of hydraulically significant structures include the S. 84th Street (STH 181) crossing of Honey Creek in the City of Milwaukee and the County Line Road (CTH Q) over the Menomonee River on the Waukesha-Washington County Line.

Based on field reconnaisance, 170, or 68 percent, of the 249 bridges or culverts on that portion of the Menomonee River watershed stream system selected for development of detailed flood hazard data were determined to be hydraulically significant. The location of these hydraulically significant bridges and culverts is shown on Map 41, whereas the number of structures on each of the selected stream reaches is set forth in Table 29. The average spacing of these hydraulically significant structures is 0.42 miles.

To meet the input data needs of the hydraulic submodel, it was necessary to obtain detailed data on these 170 structures. Data needs included measurement of the

Map 41

HYDRAULIC STRUCTURE INDEX FOR THE MENOMONEE RIVER WATERSHED: 1973



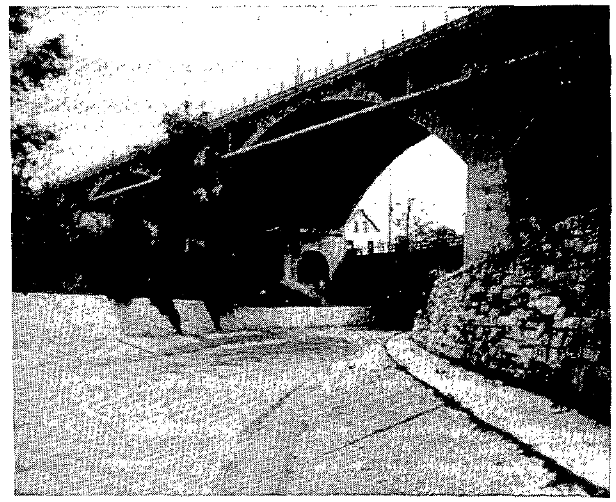
A total of 6 dams, 18 channel drop structures, and 249 bridges and culverts were inventoried during the course of the Menomonee River watershed study. Data obtained from this inventory were used to identify those dams, channel drop structures, bridges, and culverts that can be expected, by virtue of hydraulic capacity and location in the watershed, to significantly influence flood discharges and stages along the principal stream channels of the watershed. As a result of this screening process, a total of 170 bridges and culverts, 2 dams, and all 18 channel drop structures were identified for later incorporation into the water resources simulation model, as described in Chapter VIII of this volume.

Source: SEWRPC.

Figure 37

TWO EXAMPLES OF HYDRAULICALLY INSIGNIFICANT RIVER CROSSINGS IN MENOMONEE RIVER WATERSHED

Foot bridge over the Menomonee River at the North Hills Country Club in the Village of Menomonee Falls.

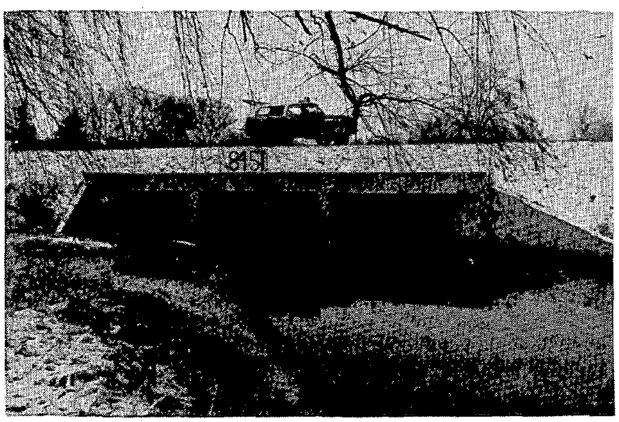


W. Wisconsin Avenue bridge over the Menomonee River in the City of Milwaukee.

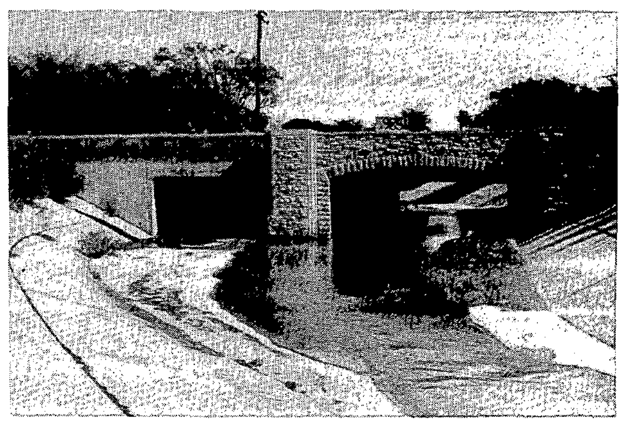
Source: SEWRPC.

Figure 38

TWO EXAMPLES OF HYDRAULICALLY SIGNIFICANT RIVER CROSSINGS IN THE MENOMONEE RIVER WATERSHED



County Line Road (CTH Q) bridge over the Menomonee River on the Waukesha-Washington County Line.



S. 84th Street (STH 181) bridge over Honey Creek in the City of Milwaukee.

Source: Alster and Associates.

waterway opening, determination of channel bottom elevations, and construction of a profile, from one side of the floodplain to the other, along the crown of the roadway or the top of rail of the railroad.

A network of vertical survey control stations referenced to Mean Sea Level Datum as determined by the U. S. Coast and Geodetic Survey was established on all hydraulically significant bridges and culverts prior to the acquisition of detailed data on the structures. Closed spirit level circuits were run to establish permanent bench marks on the upstream side of each structure to second order accuracy. At least one reference benchmark was established for each permanent bench mark and a record of vertical survey control, like that shown in Figure 39, was prepared for each hydraulically significant bridge or culvert. As part of the field survey work needed to establish the vertical survey control network, the channel bottom elevation was determined at the upstream face of each of the 170 hydraulically significant bridges and culverts, which, in addition to providing information about the waterway opening, facilitated the drawing of channel bottom profiles.

Detailed information for 54 of the 170 hydraulically significant bridges and culverts was obtained from various local agencies and units of government including the Milwaukee-Metropolitan Sewerage Commissions, the Cities of Milwaukee and Wauwatosa, the Villages of Menomonee Falls and Elm Grove, and Milwaukee County. Structure data also were provided by the Wisconsin Department of Transportation, the Chicago and Northwestern Railroad, the Milwaukee, St. Paul and Pacific Railroad, and the necessary information for the remaining 116 hydraulically significant bridges and culverts was obtained by field survey.

Prior to coding the bridge and culvert data for input to the hydraulic model, the structure information was used to draw a cross-section showing the physical con-

Figure 39

TYPICAL RECORD OF A VERTICAL CONTROL STATION ALONG THE MENOMONEE RIVER WATERSHED STREAM SYSTEM: 1973

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
RECORD OF VERTICAL CONTROL STATION
MENOMONEE RIVER WATERSHED PLANNING PROGRAM

SECTION 33 TOWNSHIP 9 N RANGE 20 E

WASHINGTON COUNTY

BENCH MARK NO. MN-59 ELEVATION 841.709'

REFERENCE BENCH MARK NO. RL-59 ELEVATION 842.281'

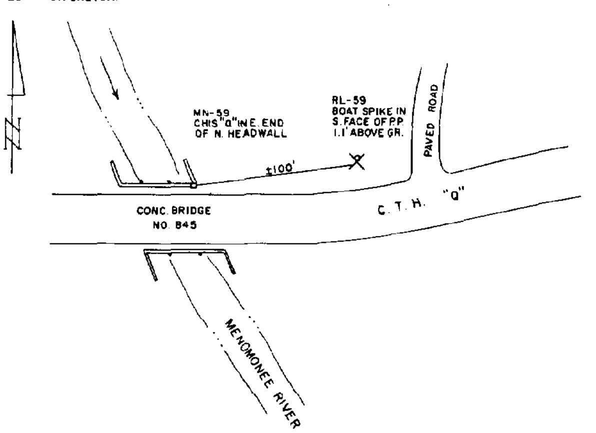
SET BY: ALSTER & ASSOCIATES, INC., ENGINEERS, MADISON, WISCONSIN

VERTICAL DATUM: MEAN SEA LEVEL, 1929 ADJUSTMENT

VERTICAL CONTROL ACCURACY: SECOND ORDER

DATE OF SURVEY: FALL, 1973 STRUCTURE NO. 845

LOCATION SKETCH:



DETAILED DESCRIPTION: STRUCTURE NO. 845 IS LOCATED NEAR THE SOUTH QUARTER CORNER OF SECTION 33, T 9 N, R 20 E.

Source: SEWRPC.

figuration of the waterway opening and the approach roads. Figure 40 shows a structure drawing typical of those prepared for each of the hydraulically significant bridges and culverts in the Menomonee River watershed.

Dams and Drop Structures: In addition to the 249 bridges and culverts located on that portion of the Menomonee River watershed stream system selected for development of detailed flood hazard information, there are six dams and 18 natural or man-made channel drops for a total of 273 hydraulic control structures. All but one of the 18 drop structures are located along the channelized segments of Underwood Creek and Honey Creek in Milwaukee County. These drop structures are an integral part of the channel modifications and provide for abrupt breaks in the channel bottom profile of the channelized reaches thereby facilitating milder slopes between the structures which in turn provide for lower velocities during flood events.

Two of the dams, the former mill dam in the Village of Menomonee Falls and the Falk Corporation dam in the City of Milwaukee, both located on the main stem of the Menomonee River, and all 18 of the channel drops were determined, by field examination, to be hydraulically significant using criteria similar to that applied to bridges and culverts. The location of the hydraulically significant dams and drop structures is shown on Map 41 whereas the number of such structures on each of the selected stream reaches is set forth in Table 29. Of the 273 hydraulic structures—bridges, culverts, dams, and drop structures—located on the stream system, a total of 190, or about 70 percent, were determined to be hydraulically significant.

The vertical survey control network discussed above was extended to the hydraulically significant dams and drop structures, and channel bottom elevations were determined at each such structure. Detailed information on the physical characteristics of some of the dams and drop structures was obtained from the Milwaukee-Metropolitan Sewerage Commissions and from the Village of Menomonee Falls. Additional necessary information was obtained by field survey. Cross-section drawings, similar to those prepared for the hydraulically significant bridges and culverts were prepared for each of the 20 hydraulically significant dams and drop structures prior to coding the data for use in the hydraulic submodel.

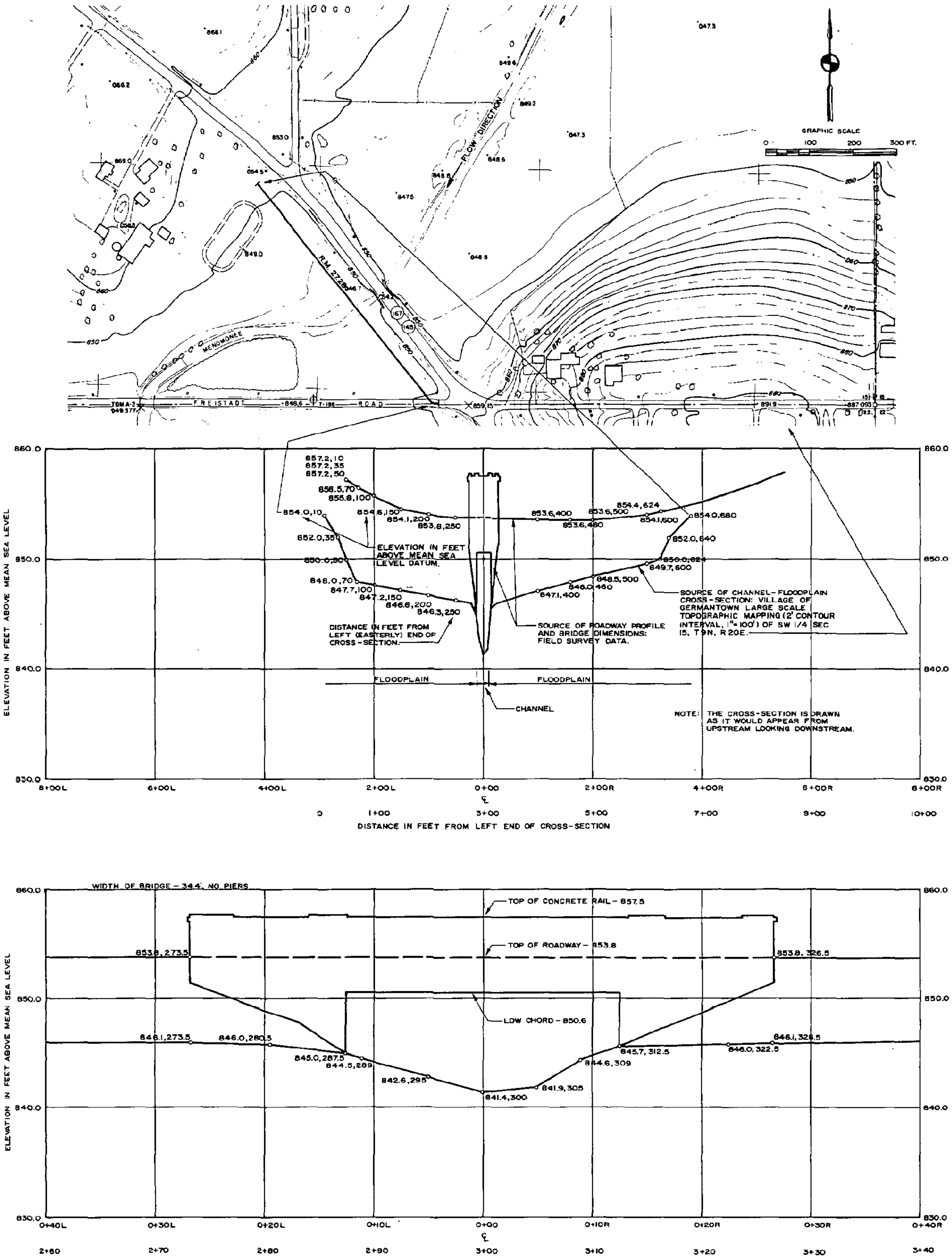
Groundwater Hydraulics

Fundamentals of Acquifer Hydraulics: Movement of groundwater can take place only if the openings in the enclosing formations are interconnected. The rate of movement is affected by the size of the openings; movement is slow in fine-grained materials and relatively rapid in coarse-grained materials. The capacity of a particular rock material or of unconsolidated deposit to transmit water is known as its hydraulic conductivity; and a formation capable of transmitting significant quantities of water to wells is called an aquifer.

Movement of groundwater between two interconnected points occurs if there is a difference in total hydraulic head between the points. Strictly defined, total hydraulic

Figure 40

TYPICAL DRAWING OF A HYDRAULIC STRUCTURE IN THE MENOMONEE RIVER WATERSHED



Source: SEWRPC.

head consists of the sum of potential energy or elevation head, pressure energy or head, and kinetic energy head. For practical purposes, however, hydraulic head is taken as the sum of elevation head and pressure head because the kinetic energy of groundwater flow is very small, relative to the other two forms of mechanical energy, and may be neglected. Flow is always down the hydraulic gradient, from an area of high hydraulic head to one of low hydraulic head.

Groundwater may occur either under water table or artesian conditions. Under water table conditions, the top of the zone of saturated subsurface materials is open directly to atmospheric pressure and defines the hydraulic head for each point in the aquifer. In the case of water table conditions, therefore, flow is from an area of high water elevation toward an area of low elevation of the water table. Under artesian conditions, the hydraulic head for a point is defined by the elevation to which water would rise in a nonpumping well penetrating the confined aquifer. While groundwater always flows down the hydraulic gradient in a confined aquifer, it does not necessarily flow from high elevation to low elevation, as under water table conditions, or from areas of high pressure to areas of low pressure. The key factor in determining the direction of groundwater flow from a particular location is the sum of the elevation head and the pressure head at that location and not their individual values.

The potentiometric surface represents the hydraulic head at all points above an aquifer. In the case of an unconfined aquifer, the potentiometric surface is coincident with the water table, whereas for confined aquifers the potentiometric surface generally lies above the zone of saturation. Potentiometric maps show, by means of contours, the potentiometric surface for a particular aquifer.

To evaluate the water supply potential or the effects of proposed development on an aquifer, the hydraulic properties of the aquifer materials must be known or estimated. Two hydraulic coefficients are used for this purpose. The hydraulic conductivity, K, of an aquifer is defined as the rate of flow of water in gallons per day through a cross-sectional area of one square foot of geological material perpendicular to the direction of flow under a unit hydraulic gradient; that is, one foot drop in head in one foot of flow distance, under prevailing temperatures. Hydraulic conductivity values can be converted so that they are expressible in units of feet per day.

The transmissivity, T, of an aquifer is defined as the rate of flow of water in gpd through a vertical strip of aquifer one foot wide, extending the full saturated thickness of an aquifer under a unit hydraulic gradient. The relationship between transmissivity and hydraulic conductivity is given by:

$$T = K \times m$$

where:

K = the hydraulic conductivity, as defined above; and

m = the saturated thickness of the aquifer in feet.

Ranges of transmissivity values for each of the three major aquifers in the Menomonee River watershed are presented in Table 28.

The storage coefficient, S, of an aquifer is the volume of water it releases from, or takes into, storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. The storage coefficient is dimensionless; in water table aquifers, the normal range is between 0.05 and 0.30 and in artesian aquifers, between 0.00001 and 0.001. Values of storage coefficients representative of the three major aquifers in the Menomonee River watershed are set forth in Table 28.

The specific capacity of a well is defined as the yield of the well, expressed in gallons per minute, per foot of drawdown in the well. In Wisconsin, water well drillers must by law perform a specific capacity test on each production well drilled. The test is accomplished by measuring the depth to the static, or nonpumping, water level in the well prior to pumping and then the depth to the pumping water level after a period of several hours of discharge at a constant rate. The difference in depth between the two measurements is the drawdown. Drawdown measured in a discharging well is a function of the hydraulic properties and local boundary conditions in the aquifer, the length and rate of discharge, and the well construction characteristics. Specific capacity data may be used to estimate the potential yield of a well and the hydraulic properties of the aquifer. Specific capacities of wells in a uniformly permeable aquifer will increase as the thickness of the aquifer open to the well increases.

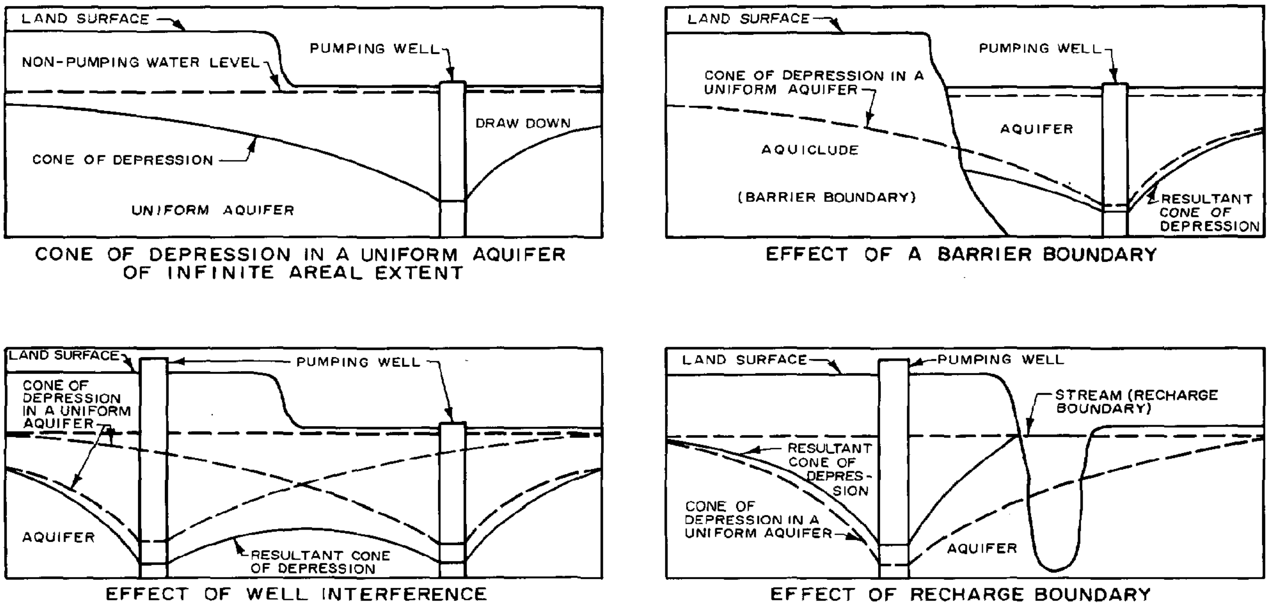
The replenishment of groundwater in an aquifer is known as recharge. Knowledge of the recharge rate to an aquifer is important because it can be used to estimate the practical rate of sustained withdrawal for the aquifer. Wherever groundwater withdrawal exceeds the recharge rate, overdraft or "mining" of the aquifer occurs; and a continuous decline of the potentiometric surface and depletion of aquifer storage results.

A well discharging from either a confined or an unconfined aquifer forms a cone of depression in the potentiometric surface around the well as groundwater flows toward the well. The cone of depression expands and deepens at a decreasing rate if there is no recharge to the aquifer. If recharge is available, the cone of depression stabilizes when the withdrawal rate becomes equivalent to the rate of recharge.

Barrier boundaries are impermeable zones in an aquifer that impede groundwater flow. When intersected by a cone of depression, a barrier boundary causes increased drawdown of the cone. Intersecting cones of depression of two or more pumping wells interfere with each other and produce effects similar to those caused by barrier

Figure 41

EFFECTS OF A BARRIER BOUNDARY, WELL INTERFERENCE, AND A RECHARGE BOUNDARY ON A CONE OF DEPRESSION



Source: U. S. Geological Survey.

boundaries. The increased drawdown caused by barrier boundaries and interfering wells is minimized by allowing sufficient distance between pumping wells and known barrier boundaries. A recharge boundary is a recharge source, such as a stream, that fully penetrates and is hydraulically interconnected to a shallow aquifer. The effect of a recharge boundary upon the cone of depression is to reduce the drawdown in the cone of depression.

The effects of barrier and recharge boundaries upon the cone of depression are shown diagrammatically in Figure 41. Barrier and recharge boundaries affecting groundwater flow in aquifers are seldom as abrupt as indicated in the figure. Gradual changes in the aquifer materials, aquifer thinning, shallow surface streams, and vertical leakage are common conditions; and each simulates diffused boundary effects during aquifer development.

The Sandstone Aquifer: The average transmissivity and storage coefficient of the sandstone aquifer, the extensive artesian water-producing unit underlying the Menomonee River watershed, have been determined to range from 3,000 to 25,000 gallons per day per foot and between 0.0001 and 0.00001, respectively. The minimum average transmissivity of the sandstone aquifer is estimated to be about 3,000 gallons per day per foot in an area where it is thinnest, in southeastern Washington County. Southerly and southeasterly of this area, transmissivity probably increases to as much as 25,000 gpd per foot as the aquifer thickness increases. West of the watershed, where the aquifer is not overlain by the Maquoketa shale, there is also an apparent increase in the aquifer transmissivity.

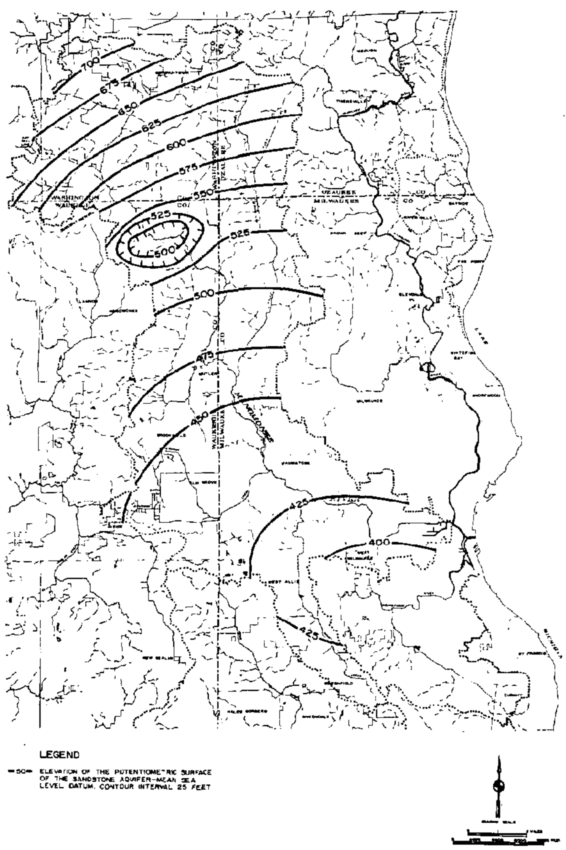
The Platteville-Galena unit, which is mainly dolomite, is considered part of the sandstone aquifer because it is left uncased in deep wells; and it is, therefore, free to contribute water to such wells. There are no wells in the watershed that obtain groundwater from this unit alone, and little is known about its hydraulic properties. The thickness of the Platteville-Galena unit is generally uniform throughout the watershed, but its hydraulic conductivity probably increases toward the west where the overlying rocks are thinner. Fracture and bedding plane hydraulic conductivity in all of the geologic formations probably is greatest along the western edge of the watershed.

The St. Peter sandstone, the uppermost sandstone unit in the sandstone aquifer, is one of the more permeable water-bearing units in the aquifer. The erosion surface upon which the St. Peter sandstone was deposited cuts across some of the underlying formations and thereby interconnects them hydraulically with the St. Peter sandstone. The Mount Simon sandstone is probably the most productive waterbearing unit in the aquifer.

Map 42 utilizes isopleths of equal hydraulic head to depict the potentiometric surface of the sandstone aquifer. The elevation of the potentiometric surface ranges from a high of about 700 feet above mean sea level datum in the extreme northwestern corner of the watershed to a low of about 400 feet above mean sea level datum in the Menomonee River industrial valley near the outlet of the watershed. The potentiometric surface declines 300 feet over a distance of about 20 miles from the headwaters of the watershed to its eastern extremity.

Map 42

GENERALIZED POTENTIOMETRIC SURFACE OF THE SANDSTONE AQUIFER IN THE MENOMONEE RIVER WATERSHED: 1973



The elevation of the potentiometric surface—the elevation to which water would rise in an open well tapping the aquifer—of the deep sandstone aquifer ranges from a high of about 700 feet above mean sea level datum in the extreme northwestern corner of the watershed to a low of about 400 feet above mean sea level datum in the industrial valley near the outlet of the watershed. The potentiometric surface of this aquifer has declined locally by over 400 feet since this water-bearing strata was first tapped in about 1880. As a consequence, communities in the watershed who have historically depended on the sandstone aquifer for public water supply are now studying alternative means of insuring a constant supply of cheap, good quality water.

Source: U. S. Geological Survey.

At the location in the northwest corner of the Village of Germantown where the potentiometric surface of the sandstone aquifer is at its highest elevation in the watershed, the potentiometric surface is positioned about 200 feet below the ground surface and about 300 feet above the surface of the sandstone aquifer—indicating that groundwater in the sandstone aquifer immediately below the confining Maquoketa shale occurs at a pressure of about 130 pounds per square inch. In the Menomonee River industrial valley, where the potentiometric surface of the sandstone aquifer is at its lowest elevation in the watershed, that surface is located about 180 feet below both the level of Lake Michigan and the land surface—both of which are at an elevation of about 580 feet above mean sea level datum—and about 400 feet above the surface of the sandstone aquifer. Although the potentiometric surface of the sandstone aquifer is 300 feet lower at the outlet of the watershed point than it is in the watershed headwater areas, the vertical distance between the potentiometric surface and the top of the sandstone aquifer is about the same—300 to 400 feet—because, as described earlier in this chapter, the sandstone aquifer slopes downward in a generally easterly-southeasterly direction.

The direction of groundwater movement in the sandstone aquifer is defined by the potentiometric surface of the aquifer. As discussed earlier, flow occurs down the hydraulic gradient, and, therefore, in a direction perpendicular to the isopleths on the potentiometric map. Map 42 indicates that groundwater in most of the sandstone aquifer flows in a generally southerly-southeasterly direction toward a concentration of wells in the Milwaukee area. Exceptions to this prevailing flow pattern are the northerly groundwater flow evident in the Honey Creek portions of the watershed and the cone of depression evident around the urbanized area of the Village of Menomonee Falls.

The potentiometric surface of the sandstone aquifer sloped gently eastward throughout the watershed in 1880, when the sandstone aquifer was first tapped by wells. Wells in the aquifer in the Milwaukee area generally flowed at the surface as the result of the artesian pressure. Subsequent development of the aquifer in the Milwaukee area has resulted in a decline of the potentiometric surface in excess of 400 feet locally; consequently, wells no longer flow.

Figure 42 illustrates the steady drop in the potentiometric surface since 1946—about four feet per year—as observed at a sandstone aquifer well located in Whitnall Park about three miles west of the southern tip of the watershed. Within the Menomonee River watershed, as indicated above, the potentiometric surface of the sandstone aquifer has declined so that it is now, in the lower reaches of the watershed, about 180 feet below the level of Lake Michigan.

As noted earlier, a small amount of sandstone aquifer recharge occurs as downward flow through the Maquoketa shale from the overlying dolomite aquifer. This flow occurs because there is a hydraulic head difference between the dolomite and sandstone aquifer. The difference in elevation between the potentiometric surfaces of these two aquifers defines the approximate head difference acting across the Maquoketa shale at any locality. If the vertical permeability of the Maquoketa shale is assumed to be uniform, leakage will be greatest where the head differences are largest.

Map 42 indicates the potentiometric surface of the sandstone aquifer, and Map 43 indicates the potentiometric surface for the combined dolomite aquifer and the glacial deposits. A comparison of the two maps indicates that the elevation of the potentiometric surface of the combined dolomite aquifer and glacial deposits is greater than the potentiometric surface of the sandstone aquifer throughout the watershed; therefore, some downward flow must occur through the Maquoketa shale. The vertical hydraulic conductivity of the Maquoketa shale is estimated to be about 0.00008 gpd per square foot, and it is accordingly estimated that less than 2,230 gpd per square mile of leakage can occur under prevailing hydraulic conditions through the Maquoketa shale under the watershed.

Because of the head difference between these aquifers, deep wells encased in both the dolomite and sandstone aquifers allow easy movement of water from the dolomite aquifer into the sandstone aquifer. This leakage or recharge to the sandstone aquifer in the Milwaukee area is significant. In 1950, recharge was estimated to average about 5.5 million gallons per day through approximately 100 wells, an average of about 55,000 gallons per day per well.

The Dolomite Aquifer: Permeability in the dolomite aquifer is due primarily to enlargement by groundwater solution of bedding planes, fractures, and other crevices that are irregularly distributed both areally and vertically within the aquifer. The upper part of the aquifer, the part most affected by erosion, may be more permeable than the lower part. Areas of greater permeability may be present within, and adjacent to, preglacial valleys.

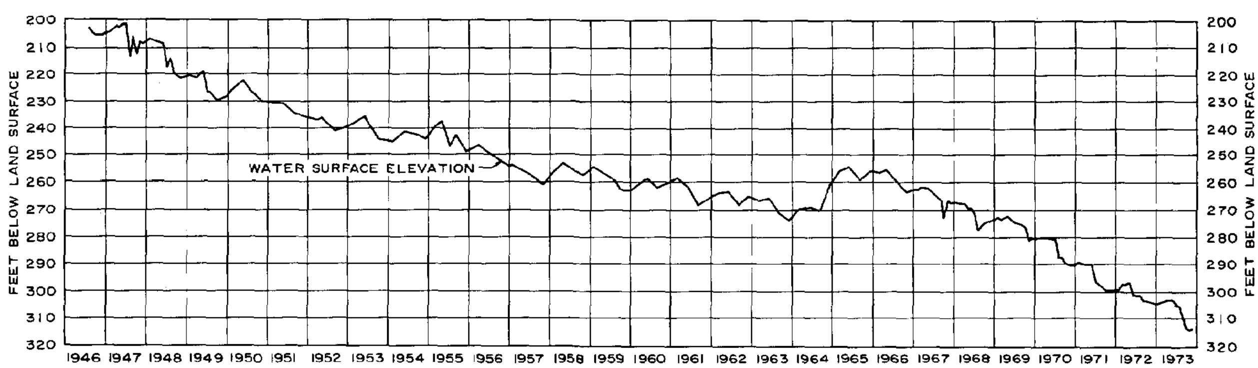
The effective average transmissivity of the aquifer in the watershed is estimated to range between 2,000 and 10,000 gallons per day per foot; and the storage coefficient is generally within the artesian range, between 0.0001 and 0.005. Water table conditions may occur locally where the saturated glacial deposits overlying the dolomite are either thin, absent, or coarse-grained. The storage coefficient resulting from long-term, large-scale aquifer development will probably be semi-artesian—that is, intermediate between water table and artesian—as the result of vertical leakage from the glacial deposits.

The potentiometric surface for the combined dolomite aquifer and glacial deposits, as shown on Map 43, approximately defines the direction of groundwater movements in these units in the watershed. Movement is down the hydraulic gradient toward discharge areas along lowland streams and lakes. Pumpage from the dolomite aquifer and leakage from the aquifer through uncased wells into the sandstone aquifer in the Milwaukee and in other areas of the watershed has produced cones of depression in the potentiometric surface of the dolomite aquifer.

In contrast with the long term, continuous, and significant declines that have occurred in the sandstone aquifer potentiometric surface, the potentiometric surface of the combined dolomite aquifer and sand and gravel aquifer has exhibited only short term fluctuations. Figure 43 illustrates short term potentiometric surface fluctuations typical of the dolomite aquifer in and near the watershed as observed since 1946 at a well located in the southwestern corner of the watershed at Greenfield Park in Milwaukee County.

Figure 42

HYDROGRAPH OF A WELL IN THE SANDSTONE AQUIFER: 1946-1973



MILWAUKEE CO., Well-94

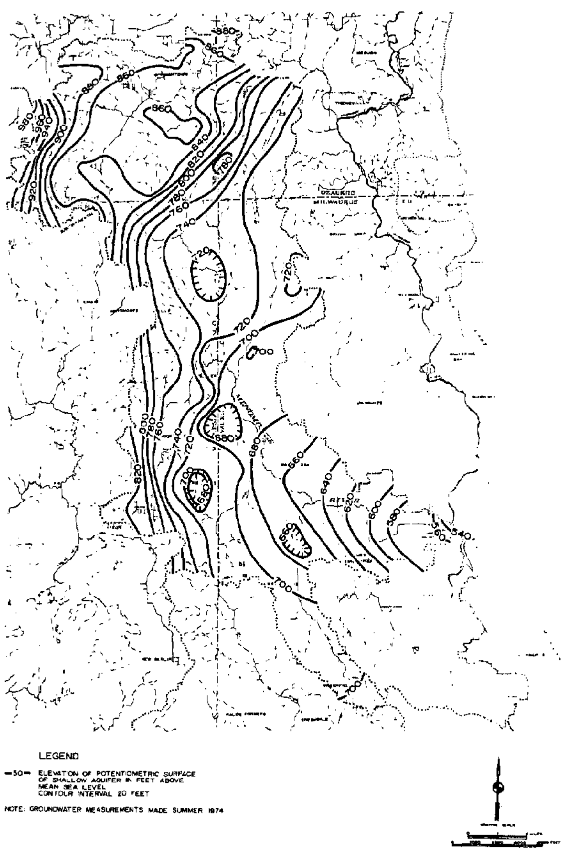
M1-6/21/32-94

Whitnall Park, NE¼SE¼ sec. 32, T6N, R21E. Drilled public-supply artesian well in sandstone of Cambrian age and St. Peter Sandstone, diam 10 in, reported depth 1,845 ft., cased to 525. Lsd 733 ft. above msl. MP top of pipe on side of concrete pump base, 14.21 ft. below lsd. Measured monthly. All plotted.

Source: U. S. Geological Survey.

Map 43

GENERALIZED POTENTIOMETRIC SURFACE OF THE DOLOMITE AQUIFER AND GLACIAL DEPOSITS IN THE MENOMONEE RIVER WATERSHED: 1974



The approximate direction of groundwater movement in the dolomite aquifer and glacial deposits in the watershed is shown by the above map of the potentiometric surface—the elevation to which water would rise in an open well tapping the aquifer. Movement is down the hydraulic gradient toward discharge zones generally located along streams or in heavily pumped areas. Natural discharge of the dolomite aquifer to streams and lakes in the low-lands occurs as upward seepage through overlying glacial deposits. Groundwater discharge sustains the dry-weather flow of streams in the watershed.

Source: U. S. Geological Survey.

Natural discharge of the dolomite aquifer to streams, ponds, and other low lying areas occurs as upward seepage through overlying glacial deposits. The annual rate of contribution to stream flow from the dolomite aquifer is probably very small. Groundwater in the dolomite aquifer and the glacial deposits of the watershed discharges to streams outside the watershed in places along the east edge. Groundwater gained from, or lost to, areas outside the watershed is known as underflow.

As noted above, a small amount of discharge takes place downward to the sandstone aquifer as a result of head differences produced by pumping in the deeper aquifer. Discharge of the dolomite aquifer also occurs through wells. Rural domestic and farm supplies are generally obtained from the dolomite aquifer through 6- to 10-inch diameter drilled wells. These wells are generally constructed to yield less than 20 gpm each.

The Sand and Gravel Aquifer: Specific capacity tests indicate that the transmissivity in the sand and gravel aquifer is at least 200,000 gpd per foot, and the storage coefficient is in the water table range. Artesian and semi-artesian storage coefficients probably prevail where the sand and gravel aquifers are overlain by extensive, saturated, fine-grained glacial deposits.

Water in the subsurface moves downward through the soils to the water table and then laterally toward streams and lakes, where it discharges as seepage. The potentiometric surface for the combined dolomite aquifer and glacial deposits, as shown on Map 43, defines approximately the direction of movement of the groundwater in these units and also the approximate elevation of the static water levels in wells tapping these units. Natural discharge of groundwater in the glacial deposits occurs as seepage into the surface water system, by direct evaporation to the atmosphere where the water table is shallow, by plant transpiration during growing seasons, and by infiltration to the dolomite aquifer. Groundwater discharge, primarily from glacial deposits, sustains the dry-weather flow of streams. For the 35 year period of 1940-1974, the average groundwater discharge to streams in the watershed is estimated to range between 0.60 and 7.20 inches annually—28,600 to 343,300 gpd per square mile—for an average annual groundwater discharge of 3.34 inches or 159,000 gpd per square mile. Areas underlain by water table sand and gravel aquifers have comparatively high sustained flow during periods of low flow, reflecting the high storage capacity of the sand and gravel.

Groundwater from the sand and gravel aquifer is also discharged through wells. Groundwater withdrawals are expected to increase in the northern parts of the watershed as population and economic growth continue.

Groundwater-Surface Water Relationships

Groundwater, surface water, and the physical environment in which they occur form a complex, but interrelated, hydraulic-hydrologic system. The degree of relation between the ground and surface water components of the system depends upon the hydrologic-hydraulic properties of the geologic formations in contact with surface water streams and lakes and the differences in hydraulic head acting between them.

Glacial deposits are the principal groundwater units interconnected with the surface water units in the watershed; where the glacial deposits are absent, surface water is hydraulically connected with the dolomite aquifer. A very poor interconnection exists between surface water and the sandstone aquifer because of the great thickness and variability of the geologic formations separating them.

The types of soils and surficial geologic materials underlying a watershed are major factors governing the characteristics of stream runoff, groundwater recharge, and groundwater discharge. Infiltration of precipitation into fine-grained materials is slow; and streams discharging from watersheds underlain by these materials are generally characterized by high-intensity, short-duration peak runoff and very small low flows. Infiltration of precipitation is more rapid in permeable materials; consequently, stream discharge from watersheds consisting of permeable units usually is more uniformally distributed in time. Peak streamflow is generally of low intensity and long duration, and the flows are moderate to high.

The process of urbanization changes the hydrologic-hydraulic conditions of the natural environment by increasing the percentage of impermeable cover on the surface and improving the natural drainage of an area. Roads, parking lots, housing, storm sewers, culverts, and drainage ditches are the types of structures that accomplish this change. The net effect of urban development on the natural hydrologic-hydraulic system generally is to reduce the rate of groundwater recharge and decrease natural detention and storage on the ground surface, thereby increasing the intensity of peak runoff from an area.

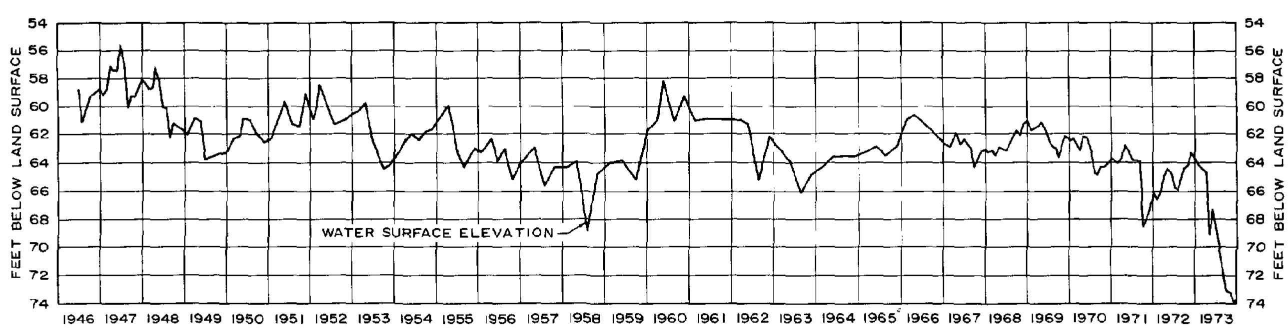
Under normal conditions, groundwater in the glacial deposits discharges to the surface water streams and lakes. The rate of discharge depends upon the hydraulic properties of the glacial deposits, the bottom materials of the streams of lakes, and the difference in hydraulic head acting across the stream bottom materials. The hydraulic interconnection between surface water and water table sand and gravel aquifers is generally good. Therefore, pumpage from wells located in the sand and gravel aquifer units within a few hundred feet of a stream or lake can reverse the natural groundwater flow and induce surface water into the aquifer. In general, the closer the well is to the stream, the greater will be the rate of induced infiltration of surface water. The maximum rate of infiltration is reached when the cone of depression in the aquifer is at the same elevation as the bottom of the stream or lake. Additional drawdown of the cone below the stream or lake bottom does not increase the rate of infiltration.

At sites where the streamflow is large, relative to the rate of groundwater withdrawal, the problem of flow depletion due to induced infiltration should not be significant. When the surface water supply is small compared to withdrawal rates, considerable depletion of streamflow may result. Depletion problems, if any, will be most acute during warm seasons when surface supplies are comparatively small and the demand for water is large.

Flow-depletion problems may be minimized by discharging used groundwater—that is, water pumped from the sand and gravel aquifers—back into the streams near the sites where it is withdrawn and by using the dolomite aquifer or the sandstone aquifer as the source of supply. Because of the poor hydraulic connection existing between these aquifers and surface waters, pumping them should not measurably affect the surface water system, although it does temporarily remove groundwater from storage. If sufficient hydrologic-hydraulic data are available for the sand and gravel aquifer at a site where serious flow depletion is anticipated, the depletion problems may be controlled or reduced through management of the groundwater-surface water systems.

Figure 43

HYDROGRAPH OF A WELL IN THE DOLOMITE AQUIFER: 1946-1973



MILWAUKEE CO., Well-130 M1-6/21/6-130

Greenfield Park, NW¼NW¼ sec. 6, T6N, R21E. Drilled public-supply artesian well in Niagara Dolomite, diam 10 in, reported depth 500 ft. Lsd 788 ft. above msl. MP hole in pump base, 8.00 ft below lsd. Measured monthly. All plotted.

Source: U. S. Geological Survey.

Surface water may be used to recharge aquifers where the conditions are favorable. The method generally involves diverting excess surface water into specially designed ponds, lagoons, or basins for infiltration into aquifers through bottoms that have a relatively high permeability. Artificial recharge permits groundwater withdrawals far in excess of the rate of the natural recharge and is a useful groundwater management technique.

HYDROLOGIC-HYDRAULIC CHARACTERISTICS BY SUBWATERSHED

The Menomonee River watershed may be considered to be a composite of 14 subwatersheds, as shown on Map 44, each of which is defined as the area directly tributary to the 14 stream reaches selected for application of hydrologic-hydraulic simulation culminating in the development of detailed flood hazard data. These subwatersheds range in size from the Little Menomonee Creek subwatershed which encompasses 3.31 square miles, or 2.4 percent of the total watershed area, to the Upper Menomonee River subwatershed, which encompasses 29.1 square miles, or 21.5 percent of the total watershed area.

Subdivision of the Menomonee River watershed into the 14 subwatersheds provides a framework for a more detailed analysis of the hydrologic-hydraulic characteristics of the watershed and for presentation of data relevant to such analysis. Whereas previous sections of this chapter have described watershed hydrologic-hydraulic characteristics on the basis of the entire watershed, this last section of the chapter presents hydrologic and hydraulic data for each subwatershed. More specifically, data and information on subbasins, soils, land use, channel slopes, hydraulic structures, and channel modifications are presented and discussed below. Summaries of hydrologic and hydraulic data by subwatershed are set forth in Tables 29 and 30, respectively.

Since the surface water runoff characteristics may vary profoundly from subwatershed to subwatershed, emphasis is placed on those subwatershed characteristics which affect surface water runoff. Such a discussion is essential to the attainment of a proper understanding of the hydrologic-hydraulic simulation model developed for the watershed. The subwatersheds are discussed in order of their contribution to flow to the watershed stream system beginning with the North Branch of the Menomonee River in the watershed headwater areas and ending with the Lower Menomonee River in the intensely urbanized lower portion of the watershed.

One conclusion that follows from a subwatershed by subwatershed examination of the hydrologic-hydraulic features of the Menomonee River watershed is that those features are extremely variable within the watershed. This relatively small watershed is a microcosm of the seven-county Region, and perhaps of an even larger geographic area, in that it contains a relatively complete range of possible land uses and land use activities and associated hydrologic-hydraulic characteristics. Natural woodlands and wetlands located in the northern headwater areas of the watershed stand in sharp contrast to the intensely developed business, commercial, and industrial complex located in the lower reaches of the watershed. The natural channels and attendant riverine areas of the upper watershed are strikingly different than the channelized reaches of the lower watershed.

Hydrologic-hydraulic simulation modeling, the application of which is described in Chapter VIII, "Water Resource Simulation Model," requires that the subwatersheds be further subdivided into subbasins. A total of 244 subbasins was delineated in the watershed, as shown on Map 45, ranging in size from 0.062 to 1.63 square miles and having an average area of 0.56 square miles. These subbasins were delineated using the best available topographic maps ranging from large scale 1" = 100', 2 foot contour interval maps to 1" = 2000', 10 foot contour interval U. S. Geological Survey quadrangle maps. The maps were supplemented with street grade data and information on the location, configuration, and elevation of storm and combined sewer systems.

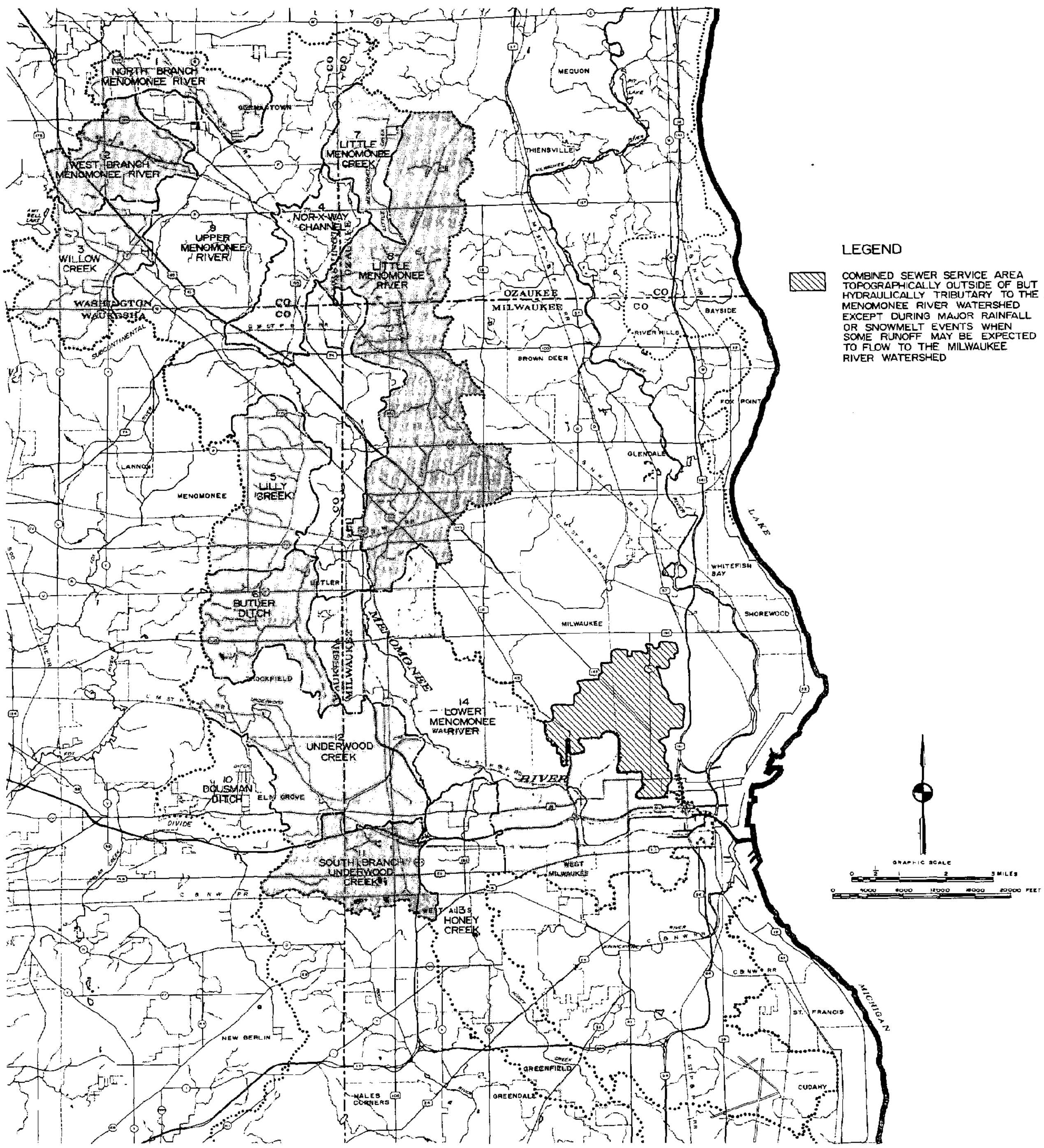
Many factors entered into the delineation of the subbasins. Some of these were strictly hydrologic-hydraulic factors while others were more directly related to the plan preparation and implementation. Subbasins were delineated so as to encompass areas tributary to intermittent streams, drainageways, and storm sewers even though those streams and drainageways may not have been selected for development of detailed flood hazard data under the watershed planning program since such delineations may be useful in subsequent extensions and refinements of the Menomonee River watershed plan. The boundaries of subbasins were selected so as to reflect relatively homogeneous hydrologic soil groups, land use, vegetal cover, and land slope. The existence of prominent natural features, such as potential sites for surface water impoundments, and prominent man-made features, such as dams and long and high railroad and roadway embankments, entered into selection of the discharge point for some subbasins. Subbasins were delineated so as to terminate at streamflow and water quality monitoring stations and at county, village, and city boundaries. Urban area subbasins were restricted to a maximum size of about two square miles to permit the development of hydrologic data consistent with the Wisconsin Department of Natural Resources guideline requiring consideration of floodplain regulations for stream reaches having a tributary area in excess of two square miles. Some subbasins were established to correspond with special interest areas such as those likely to be subject to urbanization pressures or other significant land use changes.

North Branch of the Menomonee River Subwatershed

This subwatershed is located in the northern most headwater area of the watershed and encompasses parts of the Village and Town of Germantown in Washington County. The subwatershed is directly tributary to the Upper Menomonee River, has an areal extent of 4.26 square miles, or 3.1 percent of the total watershed area, and is divided into six subbasins.

Map 44

SUBWATERSHEDS OF THE MENOMONEE RIVER WATERSHED

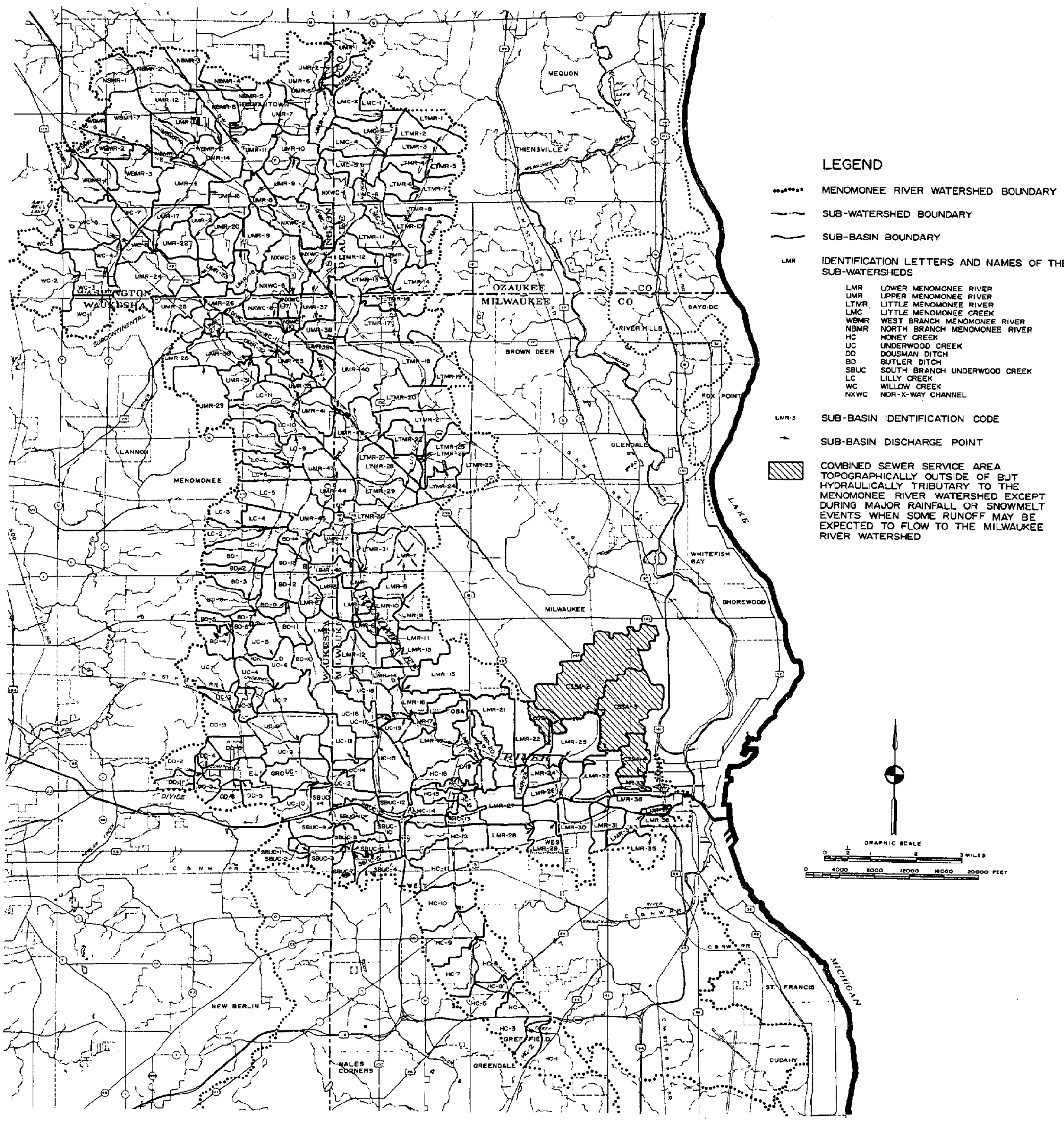


Fourteen subwatersheds were delineated within the Menomonee River watershed, ranging in area from the Little Menomonee Creek subwatershed, of about 3.3 square miles in area, to the Upper Menomonee River subwatershed, of about 29.1 square miles in area. In addition to providing rational units for hydrologic analysis, the subwatersheds serve as geographic units that enable a watershed resident to readily identify the relationship of his local drainage area to the larger Menomonee River watershed.

Source: SEWRPC.

Map 45

SUBBASINS OF THE MENOMONEE RIVER WATERSHED



A total of 244 subbasins were delineated within the Menomonee River watershed for purposes of hydrologic analyses, ranging in size from 0.06 to 1.63 square miles and having an average area of 0.56 square miles. The boundaries of subbasins were selected so as to reflect relatively homogeneous hydrologic soil groups, land use, vegetal cover, and land slope, and thus permit more ready characterization of hydrologic behavior.

Source: SEWRPC.

Ground elevations in the subwatershed are generally in the range of 850 to 950 feet above mean sea level datum and therefore the subwatershed includes some of the topographically highest land in the Menomonee River watershed. Hydrologic Soil Group B, which normally generates only moderate runoff volumes, is the principal soil type in the subwatershed covering about 43.2 percent of the subwatershed area.

The North Branch of the Menomonee River subwatershed is still in essentially rural land use, with about 92.9 percent of the 1970 land uses being in the rural category. The dominant rural land use is agriculture which accounts for about 79.8 percent of the subwatershed area.

The 1.83 miles of the North Branch of the Menomonee River selected for development of detailed flood hazard information have an average slope of 21 feet per mile. There are four hydraulically significant bridges and culverts crossing the North Branch of the Menomonee River in this subwatershed.

West Branch of the Menomonee River Subwatershed

Located in the northern headwaters of the Menomonee River watershed, this subwatershed includes parts of the Village of Germantown and the Town of Richfield in Washington County. The subwatershed has an area of 4.45 square miles, or 3.28 percent of the watershed area, is divided into 10 subbasins, and is directly tributary to the Upper Menomonee River.

Subwatershed land surface elevations are in the range of 850 to over 1,050 feet above mean sea level datum and this subwatershed, along with the Willow Creek subwatershed, contains the topographically highest land within the Menomonee River watershed. Hydrologic Soil Group B, which generally produces only moderate amounts of runoff, is the dominant soil type, covering about 66.1 percent of the subwatershed area.

Rural land uses are by far the most common in the West Branch of the Menomonee River subwatershed, accounting for 85.0 percent of the subwatershed area. The dominant rural land use is agriculture which encompasses about 75.7 percent of the subwatershed.

The 2.05 miles of the West Branch of the Menomonee River selected for development of detailed flood hazard data have an average slope of 19 feet per mile. There are six hydraulically significant bridges and culverts crossing the West Branch of the Menomonee River in this subwatershed.

Willow Creek Subwatershed

Most of this headwater subwatershed is located in the western extremities of the watershed. It encompasses parts of four civil divisions: the Village of Germantown and the Town of Richfield in Washington County and the Village of Menomonee Falls and the Town of Lisbon in Waukesha County. The subwatershed is directly tributary to the Upper Menomonee River, has an areal extent of 6.34 square miles, or 4.67 percent of the total watershed area, and is divided into eight subbasins.

Ground elevations in the subwatershed are generally in the range of 850 to over 1,050 feet above mean sea level datum. This subwatershed, along with the West Branch of the Menomonee River subwatershed, contains some of the topographically highest land in the watershed. Hydrologic Soil Group B, which normally generates only moderate runoff volumes, is the principal soil type in the subwatershed covering about 50.8 percent of the subwatershed area.

The Willow Creek subwatershed is still in essentially rural land use, with about 78.5 percent of the 1970 land uses in the rural, as opposed to the urban category. The dominant rural land use is agriculture which accounts for about 65.9 percent of the subwatershed area.

The 1.65 miles of Willow Creek selected for development of detailed flood hazard information have an average slope of 12 feet per mile. There are three hydraulically significant bridges and culverts crossing Willow Creek in the Willow Creek Subwatershed.

Nor-X-Way Channel Subwatershed

Located in the upper third of the Menomonee River watershed, this long and narrow subwatershed includes parts of the Village of Germantown in Washington County, the City of Mequon in Ozaukee County, and the Village of Menomonee Falls in Waukesha County. The subwatershed has an area of 5.26 square miles, or 3.9 percent of the watershed area, is divided into 11 subbasins, and is directly tributary to the Upper Menomonee River.

Subwatershed land surface elevations are generally in the range of 750 to 950 feet above mean sea level datum. Hydrologic Soil Group C, which generally produces large amounts of runoff, is the dominant soil types covering about 67.4 percent of the subwatershed area.

Rural land uses are by far the most common in the Nor-X-Way Channel subwatershed, accounting for 80.0 percent of the subwatershed area. The dominant rural land use is agriculture which encompasses about 65.9 percent of the subwatershed.

The 2.08 miles of the Nor-X-Way Channel selected for development of detailed flood hazard information have an average slope of 15 feet per mile. There are 10 hydraulically significant bridges and culverts crossing the Nor-X-Way channel and major channelization work has been conducted on a 0.69 mile segment of the lower end of the channel and a 0.33 mile segment of the channel in the northern part of the Village of Menomonee Falls.

Lilly Creek Subwatershed

This subwatershed is located along the western edge of the middle third of the watershed and lies entirely within the Village of Menomonee Falls. The subwatershed is directly tributary to the upper Menomonee River, has an areal extent of 5.16 square miles, or 4.53 percent of the total watershed area, and is divided into 11 subbasins.

Ground elevations in the subwatershed are generally in the range of 750 to 900 feet above mean sea level datum. Hydrologic Soil Group C, which normally generates large runoff volumes, is the principal soil type in the subwatershed, covering about 80.1 percent of the subwatershed area.

Although urban development is evident at many locations throughout the Lilly Creek subwatershed, the subwatershed remains primarily rural with about 57.8 percent of the 1970 land uses in the rural, as opposed to urban, category. The dominant rural land use is agricultural which accounts for 48.3 percent of the subwatershed area.

The 3.29 miles of Lilly Creek selected for development of detailed flood hazard information have an average slope of 11 feet per mile. There are 12 hydraulically significant bridges and culverts crossing Lilly Creek in this subwatershed.

Butler Ditch Subwatershed

Located along the western edge of the middle third of the watershed, this subwatershed includes parts of the Village of Menomonee Falls and the City of Brookfield. The subwatershed has an area of 5.67 square miles, or 4.2 percent of the watershed area, is divided into 14 subbasins, and is directly tributary to the Upper Menomonee River.

Subwatershed land surface elevations are generally in the range of 750 to 950 feet above mean sea level datum. Hydrologic Soil Group C, which generally produces large amounts of runoff, is the dominant soil type, covering about 82.0 percent of the subwatershed area.

Urban land uses are the most common in the Butler Ditch subwatershed in that they account for 69.7 percent of the subwatershed area. The dominant urban land use is residential encompassing about 52.6 percent of the subwatershed.

Upper Menomonee River Subwatershed

This subwatershed, the largest of the 14, receives stream flow from the six previously described subwatersheds. The subwatershed encompasses parts of six civil divisions: the Village and Town of Germantown in Washington County, the City of Mequon in Ozaukee County, the Villages of Menomonee Falls and Butler in Waukesha County, and the City of Milwaukee in Milwaukee County. The subwatershed is directly tributary to the lower Menomonee River at the point where the Little Menomonee River joins the main stream of the Menomonee River, has an areal extent of 29.11 square miles, or 21.5 percent of the total watershed area, and is divided into 47 subbasins.

Ground elevations in the subwatershed vary from 650 to 950 feet above mean sea level datum. Hydrologic Soil Group C, which normally generates large runoff volumes, is the principal soil type in the subwatershed, covering about 56.0 percent of the subwatershed area.

The Upper Menomonee River subwatershed is still in essentially rural land use with about 68.5 percent of the 1970 land uses in the rural, as opposed to urban category. The dominant rural land use is agriculture which accounts for 49.2 percent of the subwatershed area. Most of the urban developments in this subwatershed are contained within the Village of Menomonee Falls.

The 16.84 miles of the Upper Menomonee River selected for development of detailed flood hazard information have an average slope of 9 feet per mile and encompass, within the Village of Menomonee Falls, some of the steepest channel slopes in the watershed. There are 32 hydraulic bridges and culverts and two hydraulically significant dams and drop structures, including the former mill dam in the Village of Menomonee Falls, that cross the Upper Menomonee River in the Upper Menomonee River subwatershed.

Little Menomonee Creek Subwatershed

Located in the northern headwaters of the Menomonee River watershed, this subwatershed includes parts of the City of Mequon in Ozaukee County and the Village of Germantown in Washington County. This is the smallest subwatershed, having an area of 3.31 square miles, or 2.44 percent of the watershed area; it is divided into seven subbasins and is directly tributary to the Little Menomonee River.

Subwatershed land surface elevations are generally in the range of 700 to 950 feet above mean sea level datum. Hydrologic Soil Group C, which generally produces large amounts of runoff, is the dominant soil type, covering about 69.3 percent of the subwatershed area.

Rural land uses are by far the most common in the Little Menomonee Creek subwatershed, accounting for 85.4 percent of the subwatershed area. The dominant rural land use is agriculture which encompasses 72.5 percent of the subwatershed.

The 2.25 miles of the Little Menomonee Creek selected for development of detailed flood hazard information have an average slope of 14 feet per mile. There are three hydraulically significant bridges and culverts crossing the Little Menomonee Creek in the Little Menomonee Creek subwatershed.

Little Menomonee River Subwatershed

This long subwatershed, which receives runoff from the Little Menomonee Creek subwatershed, encompasses parts of three civil divisions: the City of Mequon in Ozaukee County, the Village of Germantown in Washington County, and the City of Milwaukee in Milwaukee County. The subwatershed is directly tributary to the Lower Menomonee River, has an areal extent of 17.89 square miles, or 13.19 percent of the total watershed area, and is divided into 31 subbasins.

Ground elevations in the subwatershed vary from 650 to 900 feet above mean sea level datum. Hydrologic Soil Group C, which normally generates large runoff volumes, is the principal soil type in the subwatershed, covering about 68.5 percent of the subwatershed area.

A rural to urban land use transition is evident in a southerly direction in the Little Menomonee River subwatershed although the primary existing land uses are in the rural category which accounted for 61.2 percent of the subwatershed area in 1970. The dominant rural land use is agriculture which encompasses about 47.6 percent of the subwatershed area.

The 10.18 miles of the Little Menomonee River selected for development of detailed flood hazard information have an average slope of 3.5 feet per mile. There are 18 hydraulically significant bridges and culverts crossing the Little Menomonee River and major channelization has been carried out 0.31 miles of the stream, while minor channelization exists along 9.31 miles of the stream.

Dousman Ditch

Located along the western edge of the lower third of the Menomonee River watershed, this subwatershed includes parts of the City of Brookfield, the Village of Elm Grove, and the Town of Brookfield. The subwatershed has an area of 3.60 square miles, or 2.65 percent of the watershed area, is divided into nine subbasins, and is directly tributary to Underwood Creek which in turn flows into the Lower Menomonee River.

Subwatershed land surface elevations are generally in the range of 800 to 950 feet above mean sea level datum. Hydrologic Soil Group C, which generally produces large amounts of runoff, is the dominant soil type, covering about 48.9 percent of the subwatershed area.

Urban land uses are the most common in the Dousman Ditch subwatershed, accounting for 60.8 percent of the subwatershed area. The dominant urban land use is residential, encompassing about 38.9 percent of the subwatershed.

The 0.64 miles of Dousman Ditch selected for development of detailed flood hazard information have an average slope of 4.5 feet per mile. There are three hydraulically significant bridges and culverts crossing Dousman Ditch and all of the ditch has been subjected to major or minor channelization.

South Branch of Underwood Creek Subwatershed

This subwatershed, located in the lower third of the watershed, encompasses parts of five civil divisions: the Cities of Brookfield and New Berlin in Waukesha County and the Cities of West Allis, Milwaukee, and Wauwatosa in Milwaukee County. The subwatershed is directly tributary to Underwood Creek, has an areal extent of 4.98 square miles, or 3.67 percent of the total watershed area, and is divided into 14 subbasins.

Ground elevations in the subwatershed vary from 700 to 950 feet above mean sea level datum. Soils data are available for 95.8 percent of the subwatershed with Hydrologic Soil Group C, which normally generates large runoff volumes being dominant and covering about 50 percent of the area for which soils data exist.

The primary land uses in the South Branch of Underwood Creek subwatershed are in the urban category which accounted for 83.3 percent of the 1970 land uses. The dominant urban land use is residential which encompasses about 36.4 percent of the subwatershed area.

The 1.08 miles of the South Branch of Underwood Creek selected for development of detailed flood hazard information have an average slope of 5.5 feet per mile. There are four hydraulically significant bridges and culverts crossing the South Branch of Underwood Creek, and major channelization exists along its entire length.

Underwood Creek Subwatershed

Located in the western part of the lower third of the watershed, this subwatershed includes parts of the City of Brookfield and the Village of Elm Grove in Waukesha County and the Cities of Wauwatosa and Milwaukee in Milwaukee County. The subwatershed has an area of 11.26 square miles, or 8.30 percent of the watershed area, is divided into 19 subbasins, and is directly tributary to the Lower Menomonee River.

Subwatershed land surface elevations are generally in the range of 650 to 950 feet above mean sea level datum. Hydrologic Soil Group C, which generally produces large quantities of runoff, is the dominant soil type, covering about 67.5 percent of the subwatershed area.

Urban land uses prevail in the Underwood Creek subwatershed, accounting for 78.3 percent of the subwatershed area. The dominant urban land use is residential which encompasses about 41.8 percent of the subwatershed.

The 7.47 miles of Underwood Creek selected for development of detailed flood hazard information have an average slope of 20 feet per mile and are crossed by 37 hydraulically significant structures--30 bridges and culverts and seven drop structures. Major channelization has been conducted on the entire 2.57 mile long Milwaukee County reach of Underwood Creek, and 2.73 miles of minor channelization and 2.57 miles of major channelization are evident in Waukesha County along with a short 0.12 mile long reach in the Village of Elm Grove that has been completely enclosed in a conduit. Therefore, a total of 6.17 miles or 82.6 percent of Underwood Creek has been hydraulically modified.

Honey Creek Subwatershed

This long, narrow subwatershed, which forms the southern extremity of the Menomonee River watershed, encompasses parts of the five civil divisions in Milwaukee County: the Cities of Wauwatosa, Milwaukee, West Allis, and Greenfield and the Village of Greendale. The subwatershed is directly tributary to the lower Menomonee River, has an areal extent of 10.32 square miles, or 7.61 percent of the total watershed area, and is divided into 19 subbasins.

Ground elevations in the subwatershed vary from 650 to 850 feet above mean sea level datum. Soils data are available for only 33.6 percent of the subwatershed.

Hydrologic Soil Group C, which produces large amounts of runoff, is dominant and covers about 83.2 percent of the area for which soils data are available.

The principal land uses in the Honey Creek subwatershed are in the urban category. They accounted for 90.44 percent of the 1970 land uses. The dominant urban land use is residential, encompassing about 44.9 percent of the subwatershed area.

The 7.55 miles of Honey Creek selected for development of detailed flood hazard information have an average slope of 15 feet per mile. There are 31 hydraulically significant structures—21 bridges and culverts and 10 drop structures—crossing Honey Creek. Some form of channel modifications are found along the entire length of Honey Creek and consist of 0.41 miles of minor channelization, 4.20 miles of major channelization and 2.42 miles of channel that are completely encased in an underground conduit.

Lower Menomonee River Subwatershed

This subwatershed, next to the largest of the 14 subwatersheds, is positioned at the downstream end of the watershed stream system and therefore receives runoff from the other 13 subwatersheds. The subwatershed encompasses parts of six civil divisions: the City of Brookfield and the Village of Butler in Waukesha County and the Cities of Milwaukee, Wauwatosa, West Allis, and West Milwaukee in Milwaukee County. The subwatershed is directly tributary to the Milwaukee River, has an areal extent of 23.03 square miles, or 16.99 percent of the total watershed area, and is divided into 38 subbasins.

Ground elevations in the subwatershed vary from about 580 to 800 feet above mean sea level datum and, because of the subwatershed's position in the Menomonee River watershed's drainage system, it contains the lowest land in the watershed. Soils information exists for only 33.4 percent of the subwatershed with Hydrologic Soil Group C, a large producer of runoff, being dominant and accounting for 68.1 percent of the area for which soils data are available.

Almost all the Lower Menomonee River watershed is urbanized in that, as of 1970, land uses in the urban category accounted for 94.0 percent of the land in the subwatershed. The dominant urban land use is transportation, communication, and utility facilities which encompass about 34.4 percent of the Lower Menomonee River subwatershed area followed by residential land uses which cover about 32.8 percent of the subwatershed.

The 12.57 miles of the Lower Menomonee River selected for development of detailed flood hazard information have an average slope of 11.2 feet per mile. There are 21 hydraulically significant bridges and culverts and one hydraulically significant dam crossing the Lower Menomonee River—the Falk Corporation dam immediately upstream of the harbor estuary portion of the river. Much of the Lower Menomonee River has been hydraulically modified in that major channelization exists along 4.75 miles or 37.8 percent of the channel and minor channelization is evident along 2.10 miles or 16.7 percent of the channel.

SUMMARY

This chapter has described those elements of the complex hydrologic-hydraulic system of the Menomonee River watershed which constitute the framework within which all the water resource and water resource-related problems of the watershed must be analyzed and resolved. Included in the discussion of the hydrology of the watershed were quantitative data on precipitation, evapotranspiration, and other aspects of the hydrologic budget; an examination of factors such as soil types and land use that affect rainfall-runoff relationships; quantitative data on the volume and timing of runoff as revealed by stream gaging records; and data on the location and quantity of water contained within the aquifers lying beneath the watershed. Included in discussion of the hydraulics of the watershed were quantitative data on the length, slope, and flow resistance of the stream system; an evaluation of the hydraulic significance of hydraulic structures; and data on the flow characteristics of the underlying aquifers.

Quantitative knowledge of the complex hydrologic cycle as it affects the watershed is necessary to assess the availability of surface and groundwater for various uses and to improve the management potential of water during times of flooding or drought. The quantitative relationships between inflow and outflow, termed the hydrologic budget, were determined for the watershed. Precipitation is the primary source of water to the watershed and, based on nine observation stations having 20 to 50 years of record, averages 29.1 inches annually. Surface water runoff and evapotranspiration losses constitute the primary outflow from the basin. The average annual runoff approximates 8.2 inches, while the annual evapotranspiration loss totals about 20.9 inches.

Although streamflow records available for the Menomonee River stream system cover only slightly more than a decade, these records do reveal key characteristics of the watershed's hydrologic-hydraulic system. Major flood discharges in the watershed tend to result from rainfall events as opposed to either snowmelt or combined rainfall-snowmelt events, which have historically produced the major floods in the larger watersheds of southeastern Wisconsin. As a consequence, peak floods are distributed throughout the late winter, spring, and summer seasons rather than concentrated in the late winter and early spring as is the case in the larger watersheds. As a result of extensive urbanization and the attendant large extent of impervious surface and extensive storm water drainage systems and channelization works, the response of the watershed to large rainfall events is rapid in that peak discharges generally occur near the lower end of the watershed from within a fraction of a day to two days after the initiation of such an event.

Approximately 72 lineal miles of the watershed stream system were selected for development of detailed flood hazard information including discharge-frequency relationships, flood stage profiles, and mapped areas of inundation for selected flood recurrence intervals. Detailed data were obtained for 190 hydraulically significant bridges, culverts, dams, and drop structures on that portion of the stream system and approximately 933 floodland cross-sections were prepared, all of this required as input to the hydrologic-hydraulic model developed for the watershed.

There are three main groundwater aquifers beneath the watershed: the deep sandstone, the shallow dolomite, and the unconsolidated sand and gravel aquifers. The confined or artesian sandstone aquifer is the deepest of the three systems; wells tapping this aquifer are sometimes more than 2,000 feet deep and, therefore, very expensive to drill and operate. This aquifer, except for minor leakage and a connection to the recharge area, is hydraulically separated from the remainder of the hydrologic-hydraulic system by the overlying semipermeable Maquoketa shale formation. The dolomite aquifer and the unconsolidated sand and gravel aquifers are, in contrast to the sandstone aquifer, recharged locally.

The movement of groundwater through the three aquifers beneath the Menomonee River watershed is governed by the spatial variation in the magnitude of total hydraulic head which is depicted in this chapter in the form of potentiometric maps for both the deep sandstone aquifer and the combination of the shallow dolomite and sand and gravel aquifers. Groundwater in the deep sandstone aquifer beneath the aquifer moves in a generally southerly-southeasterly direction, whereas flow in the dolomite and sand and gravel aquifers tends to be more varied in that it is more influenced by the location of wells and low-lying natural discharge areas. Flow in both these aquifers generally also moves in a southerly-southeasterly direction. Well data were used to develop values for important hydraulic parameters of the groundwater aquifers such as hydraulic conductivity, transmissivity, the storage coefficient, and specific capacity.

The Menomonee River watershed may be considered as a composite of 14 subwatersheds ranging in size from the 3.3 square mile Little Menomonee Creek subwatershed to the 29.1 square mile Upper Menomonee River subwatershed. Hydrologic-hydraulic information, including soils, land use, channel slopes, hydraulic structure, and channel modification data were inventoried and analyzed for each of the subwatersheds. Marked variations in this subwatershed information reveals that the Menomonee River watershed is a microcosm of the seven-county Region containing the full spectrum of possible land uses, land use activities, and attendant hydrologic-hydraulic characteristics and problems.

Chapter VI

HISTORIC FLOOD CHARACTERISTICS AND DAMAGES

INTRODUCTION

Flooding of the stream system of the Menomonee River watershed is a common and natural occurrence. The streams of the watershed leave their channels and occupy portions of the adjacent natural floodplains almost annually as a result of late winter-early spring snowmelt or snowmelt-rainfall events or in response to spring, summer, and fall thunderstorms. Damage from this flooding has been, to a large extent, a consequence of the failure to recognize and understand the relationships which should exist between the use of land and the hydrologic-hydraulic behavior of the stream system. Unnecessary occupancy of the natural floodlands by flood-vulnerable land uses, together with development-induced changes in the flow characteristics of the streams, has substantially increased flood risks.

Comprehensive watershed planning is the first step in achieving or restoring a balance between the use of land and the hydrologic-hydraulic regimen of the watershed. To ensure that future flood damage will be held to a minimum, plans for the proper utilization of the riverine areas of the watershed must be developed so that public acquisition, land use controls, and river engineering can be used to properly direct new development into a pattern compatible with the demands of the river system on its natural floodlands and to achieve an adjustment or balance between land use development and floodwater flow and storage needs.

Flood damage potential and flood risk have grown from a nuisance level during predominantly agricultural use of the watershed to substantial proportions as urban land use has increased. Practically all of the present flood risk can be ascribed to unnecessary location of flood damage-prone urban development in the natural floodlands—unnecessary since adequate alternative locations are available within the watershed and Region for such development. Nevertheless, in the absence of a sound watershed plan, such occupation of the floodlands may be expected to continue to increase as urban development proceeds within the watershed. Much of the floodlands, however, are as yet unoccupied by flood-vulnerable urban uses; and the opportunity still exists for limiting flood damage risk through sound land use development in relation to the riverine areas of the watershed.

This chapter presents a summary of historic information on flooding and the character and nature of flooding within the watershed. This information has six important applications in watershed plan preparation and implementation; identification and delineation of flood damage-prone areas; determination of the causes of the flooding and flood damage in those areas; the calibration of the hydrologic-hydraulic simulation model; computation of monetary flood risks; formulation of alternative flood control measures; and post-plan-adoption, public information, and educational activities leading to plan implementation.

This chapter, which discusses historic flood characteristics and damage, and certain parts of Chapter IV, Volume II, "Alternative Floodland Management Measures," are directed primarily to the inventory, analysis, and resolution of flood problems along the 72 miles of stream channels in the Menomonee River watershed selected for development of detailed flood hazard data and attendant flood control plans as shown on Map 38. The Menomonee River watershed plan is intended to provide recommendations for the resolution of existing flood problems along the selected stream channel reaches and the prevention of future flood problems in the associated riverine areas. The watershed planning process is not intended to address the resolution of stormwater drainage problems not directly attributable to flooding of the watershed stream system.

Flooding is defined, for the purpose of this report, as the inundation of floodlands of the watershed which occurs along the major river and stream channels as a direct result of water moving out of and away from those rivers and streams. Flood-prone areas, which are contained within low-lying, continuous zones generally following the major stream channels, are receptive to engineering analyses on a watershed wide basis and, upon completion of such analyses, may be accurately and precisely delineated on large-scale topographic maps.

Inadequate stormwater control is defined, for the purposes of this report, as inundation which occurs when stormwater runoff moving toward rivers, streams and other low-lying areas of the watershed encounters inadequate conveyance or storage facilities and, as a result, causes localized ponding and surcharging of storm and sanitary sewers. Areas having stormwater drainage and attendant sanitary and storm sewer backup problems can only be delineated on the basis of detailed local engineering studies. In contrast to areas experiencing flooding, areas experiencing inadequate stormwater control tend to be discontinuous, consisting of a series of relatively small and scattered pockets, not necessarily located in the lowest areas or even near the major streams. The resolution of stormwater problems requires analysis of local street and associated building grades and local stormwater drainage and sanitary sewerage systems. Therefore, with the exception of stormwater control problems directly related to flood stages on the selected 72 miles of stream system in the watershed, the analysis of stormwater drainage problems is beyond the scope of the Menomonee River watershed study as set forth in the Menomonee River Watershed Planning Program Prospectus.

HISTORIC FLOODING

Historic flood data and information for the Menomonee River watershed are available for the 76-year period from March 1897 through April 1973. These data include measurements or observations of flood flows, peak river stages, and areas of inundation; personal accounts—sometimes supported with photographs—of flood flow characteristics and the resulting flood damage; and reported monetary flood losses.

Uses of Historic Flood Information

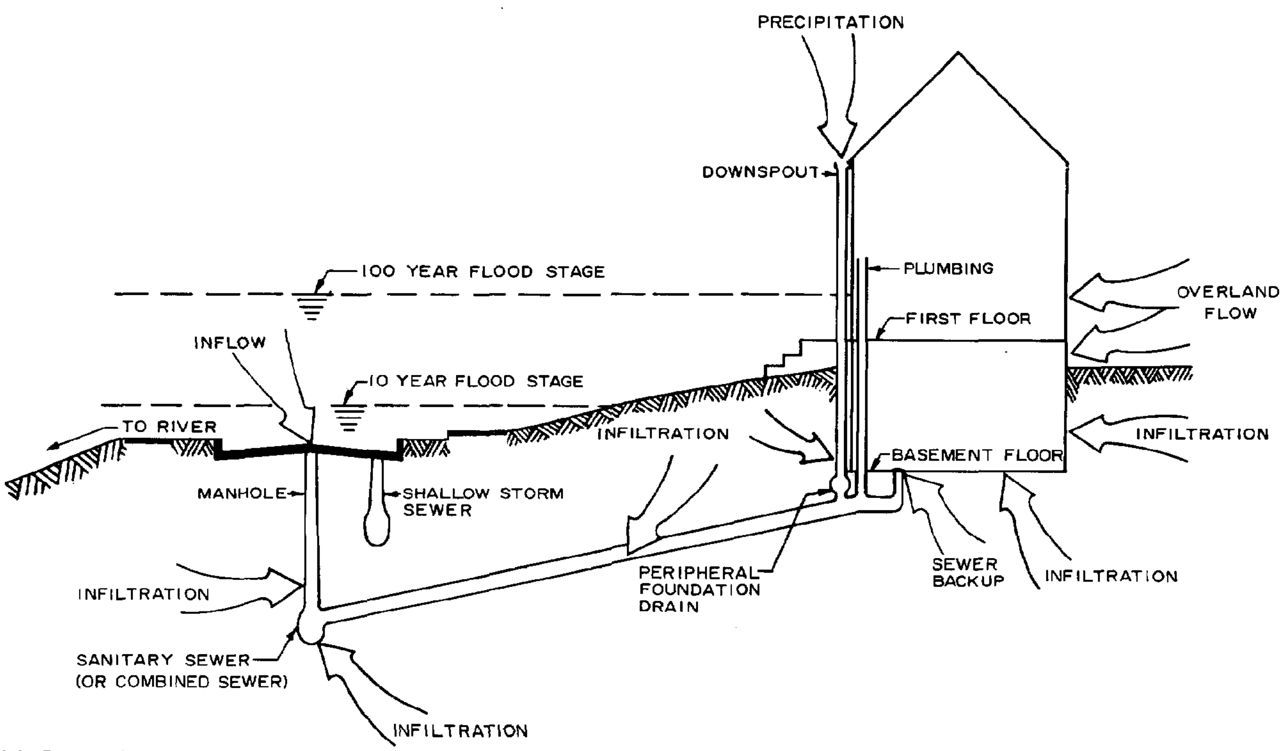
The collection, collation, and analysis of historic flood information is an important element of any comprehensive watershed study. As already noted, historic flood data have six primary applications in watershed planning and plan implementation. Five of these applications occur during the planning process and one is directly related to plan implementation.

Identification and Delineation of Flood-Prone Areas: While the location and extent of some flood-prone areas within the Menomonee River watershed were known at the outset of the watershed study, the location and extent of all such areas within the watershed was not known, nor was the existing information adequate to facilitate the development of alternative solutions to the flood problems. One important use of the historic flood information in the watershed study, therefore, was the precise identification and delineation of all riverine areas in the watershed that are not only subject to flooding, but in which the flooding either causes or has the potential for causing significant monetary flood damages.

Determination of the Cause of Flooding: Residential, commercial, and industrial structures are particularly vulnerable to flood damage partly because of the many

Figure 44

MEANS BY WHICH FLOODWATERS MAY ENTER A STRUCTURE DIRECTLY OR INDIRECTLY



NOTE: TYPICAL AND GENERALLY PREFERABLE VARIATIONS INCLUDE DOWNSPOUTS DISCHARGING TO THE GROUND SURFACE AND FOUNDATION DRAINS CONNECTED TO STORM SEWERS OR CONNECTED TO A SUMP FROM WHICH WATER IS PUMPED TO THE GROUND SURFACE AT SOME POINT AWAY FROM THE STRUCTURE

Source: SEWRPC.

ways in which floodwaters can enter such structures. As illustrated in Figure 44, an unprotected floodland structure is a virtual "sieve" with respect to the entry of floodwaters. Rising floodwaters may surcharge the sanitary, storm, or combined sewers in an urban area thereby reversing the flow in these sewers and forcing water into the structures through basement floor drains, plumbing fixtures and other openings connected to the sewer system. As a result of saturated soil conditions around the structure foundation, water may enter through cracks or structural openings in basement walls or floors. If overland flooding occurs—that is, flood stages rise above the elevation of the ground near a particular residential, commercial, or industrial structure—additional floodwater may enter the basement of the structure through basement doors, windows and other structural openings. If flood stages rise high enough, floodwaters may similarly gain access to the first or main floor of a structure. In addition to the inundation damage to the structure and its contents, external hydrostatic pressures may cause the uplift and buckling of basement floors and the collapse of basement walls. Finally, floodwaters may exert hydrostatic or dynamic forces of sufficient magnitude to lift or otherwise move a structure from its foundation.

It should be noted that flood damage can occur to the basements of structures located outside of the geographic limits of the overland flooding when floodwaters gain access to basements via the hydraulic connections between the inundated area—the area of primary flooding—and basements that are provided by the sanitary, storm, or combined sewer systems. Such flooding of basements outside of, but adjacent to, the area of primary flooding is herein defined as secondary flooding.

Calibration of the Hydrologic-Hydraulic Simulation Model: Inasmuch as flood flows, stages, and areas of inundation throughout the watershed were developed by mathematical modeling or simulation techniques, sound engineering practice requires "calibration" of the model through careful comparisons between the model results and reliable observations of the actual hydrologic-hydraulic behavior of the stream system. Such comparisons permit adjustments to and refinements in the model and thereby result in a more accurate model and representation of watershed hydrology and hydraulics. As described in Chapter VIII, "Water Resource Simulation Model," extensive use was made of historic flood information during the model calibration process.

Computation of Monetary Flood Risk: Monetary flood risks for flood events of specified recurrence intervals as well as average annual risks under existing and probable future land uses, must be determined for selected stream reaches in order to permit an economic evaluation of alternative flood control proposals. The information required to compute monetary flood risks includes: data on the type of structures affected; the elevation of the ground at the structure and the elevation of the first floor; the existence of a basement; and the market value of the structure and land excluding structure contents. Some of the necessary data for representative structures were obtained as part of the survey of historic flooding.

Formulation of Alternative Flood Control Measures: Alternative flood control measures include acquisition and removal of flood-prone structures, structure floodproofing, channel modification, and construction of dikes, floodwalls and flood control reservoirs. To be technically feasible, the measures and combinations of measures formulated for each flood-prone reach must be directed at the primary cause of the flooding. For example, earth dikes and concrete floodwalls are technically feasible solutions in river reaches that historically have been subjected to overland flooding but are not, if used alone, effective in those riverine areas that incur extensive secondary flooding. Formulation of alternative flood control measures for a particular reach is, therefore, influenced by the nature and causes of the flood problems in that reach as determined from historic flood information.

Post-Plan Adoption, Information and Education: The above-listed five uses of historic flood information relate to the preparation of comprehensive watershed plans while the sixth and last use of such information occurs during the plan implementation process after the plan is completed. Experience indicates that some segments of the public are very concerned about flood problems immediately after a flood event, whereas, with the passage of time—months and years—there is diminished concern. Other segments of the public tend to the opposite extreme, that is, exaggeration of the seriousness of the flood problem in general and specific flood events in particular.

Documented historic flood information is an effective way to bring the seriousness of flood problems into proper focus and perspective. It provides a common basis for understanding the nature of the problem in a particular locality and thus promotes implementation of the flood control recommendations contained in the adopted watershed plan. Historic flood information—in contrast with flood hazard information produced by a mathematical model—is particularly effective in improving public understanding of the need for plan implementation, since laymen can more readily understand and relate to such graphic data as a photograph of flood damage, a peak flood stage measured from and related to a bridge, or the delineation of the lateral extent of flooding based on the deposit of debris as observed in the field. A considerable amount of historic flood information has been included in this chapter so that it will be readily and widely available to both public officials and interested citizens and thereby contribute to plan implementation.

Inventory Procedure and Information Sources

A comprehensive research effort that employed a variety of procedures and information sources was required to develop the account of historic flooding in the Menomonee River watershed as presented in this chapter. The inventory of historic flooding was initiated by reviewing engineering and planning reports prepared by governmental agencies and private consulting firms and addressed to flood problems in all or parts of the watershed.[1]

Published streamflow records for the U. S. Geological Survey wire weight gage at Wauwatosa (USGS Gage 4-0871.2) were examined to identify flood flow periods and probable occurrences of flood damage in the watershed. The wire weight gage, which is the only streamflow gage in the watershed at which daily flow observations are made, has been in operation since October 1961. As discussed in Chapter V, "Hydrology and Hydraulics," the U. S. Geological Survey also maintains in cooperation with the Wisconsin Department of Transportation and the Wisconsin Department of Natural Resources, three partial record stations in the watershed, the oldest of which was established in 1959. Records for these stations were examined, as were observations made at staff or crest stage gages operated by the Milwaukee-Metropolitan Sewerage Commissions, the City of Milwaukee, and the Village of Menomonee Falls. The records from these streamflow and stage monitoring stations were useful in identifying probable flood dates over the 15-year period since about 1959.

This initial reconnaissance of published reports and data was followed by research of newspapers and newspaper files. In the research effort many potential sources were examined, a long period of history was considered, and much information was obtained on each of numerous historic floods. The principal source of information for this phase of the historic flooding inventory was the Milwaukee Journal with supplemental information from the Milwaukee Sentinel, the Menomonee Falls News, the Waukesha Freeman and the Mequon Squire. Paralleling the search of newspapers and newspaper files, the Commission staff contacted various libraries and historical societies. Useful historical flood information was obtained from the City of Milwaukee Library, the Milwaukee County Historical Society, and the Waukesha County Historical Society.

After completion of the above research, Commission staff met with local public officials to obtain historic flood data from their files and, equally important, to benefit from these local public officials' firsthand knowledge of historic and recent flood problems. Such meetings were conducted with officials of the Cities of Wauwatosa, Mequon, West Allis, Brookfield, and Milwaukee and officials of the Villages of Elm Grove, Menomonee Falls, Germantown, and Butler. Officials in almost every community were able to identify areas that had been recently subjected to overland and secondary flooding. In a few communities, such as the Cities of Milwaukee and Wauwatosa and the Villages of Menomonee Falls and Elm Grove, officials were able to provide detailed information on such matters as flood stages and areas of inundation for recent flood events.

The Commission staff then conducted field surveys during which personal interviews were conducted with the owners or tenants of riverine area structures and property. Selected information pertaining to the interviews is set forth in Table 32, while the riverine areas included in the interview program are shown on Map 46. Areas selected for interviews and the intensity of the interviewing in those areas were based largely on the findings of all of the preceding research. Field interviews, which were concentrated in those areas in which historic flood problems were known to have occurred, were conducted in portions of the Cities of Wauwatosa, Mequon, Brookfield, and Milwaukee and the Villages of Elm Grove, Menomonee Falls, and Germantown. The field surveys included personal interviews with owners or tenants of a cross section of structures, selected so as to constitute a valid, representative sample of all flood-prone structures. A total of 485 interviews was completed with the owners or tenants of a wide variety of structure types including single- and multiple-family residences, mobile homes, schools, business and commercial enterprises, manufacturing and industrial facilities, and agricultural operations.

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[1] *Engineering and planning reports that were reviewed in the preparation of the chapter and found to contain some historic flood information or to propose solutions to flooding problems are:*

"Report of Investigation of Flood Conditions at the Property of the Falk Corporation," Klug and Smith Company, September 19, 1960.

"Report on Engineering Study of Honey Creek Flood Area in West Allis, Wisconsin," Consoer, Townsend and Associates, November 1960.

"Report for Flood Control in the Milwaukee River Watershed," U. S. Department of Agriculture, Soil Conservation Service, February 1961.

"Report on Flood Control Study—Wauwatosa, Wisconsin," Greeley and Hansen Engineers, July 1961.

"Study of Underwood Creek Improvements—Lovers Lane Road to Menomonee River," A. R. Striegl, March 12, 1962.

"Report on Menomonee River Flood Survey—N. 25th Street to W. Harwood Avenue," Klug and Smith Company, June 1964.

"Survey Report for Flood Control on Milwaukee River and Tributaries," U. S. Army District—Chicago, Corps of Engineers, November 1964.

"Report on Proposed Underwood Creek Improvements through the Underwood Creek Parkway—Bluemound Road to Watertown Plank Road," Hartman—Strass, Inc., December 1967.

Copies of these reports are available for examination at the Commission offices.

Table 32

SELECTED INFORMATION ON INTERVIEWS CONDUCTED TO OBTAIN HISTORIC FLOOD INFORMATION AND STRUCTURE DATA IN THE MENOMONEE RIVER WATERSHED

County	Civil Division[a]	Streams Along Which Interviews Were Conducted	Period During Which Interviews Were Conducted Month-Year	Number of Interviews Completed With Owners or Tenants by Type of Structure or Property									
				Single-Family Residence	Two-Family Residence	Multi-Family Residence	Mobile Home	Business-Commercial	Manufacturing-Industrial	School	Agricultural	Other	Total
Milwaukee	City of Wauwatosa	Honey Creek Menomonee River Underwood Creek Grantosa Tributary	August, September, and October 1974	107	7	1	0	13	12	3	0	4	147
Ozaukee	City of Mequon	Little Menomonee River Little Menomonee Creek	October 1974	15	1	0	0	1	0	0	0	0	17
Washington	Village of Germantown	Willow Creek Upper Menomonee River West Branch Menomonee River North Branch Menomonee River	September 1974	14	0	0	0	1	0	0	0	0	15
Waukesha	City of Brookfield	Butler Ditch Underwood Creek Dousman Ditch	September-October 1974	49	0	0	0	0	0	0	0	0	49
	Village of Elm Grove	Underwood Creek Fox Run	August 1974	35	0	1	0	25	0	1	0	3	65
	Village of Menomonee Falls Lilly Creek	Menomonee River Nor-X-Way Channel	August-September 1974	164	4	5	0	17	1	1	0	0	192
Total	--	--	--	384	12	7	0	57	13	5	0	7	485

[a] *Interviews were conducted with property owners or tenants in six of the 17 cities, villages, and towns located wholly or partly in the Menomonee River Watershed. Interviews were not conducted in the Cities of Greenfield, Milwaukee, West Allis, and New Berlin; the Villages of Greendale, West Milwaukee, and Butler; and the Towns of Germantown, Richfield, Brookfield, and Lisbon, because a preliminary survey of historic flood information indicated that these communities had no or only minor flood problems.*

Source: SEWRPC.

The form used to interview the owner or tenant of a structure is reproduced as Figure 45. As indicated by the sample form, the interviews were intended to provide information about the structure occupied by the owner or tenant as well as information about historic flood events that either affected the structure or had effects on the land used in conjunction with the structure.

Method of Presentation

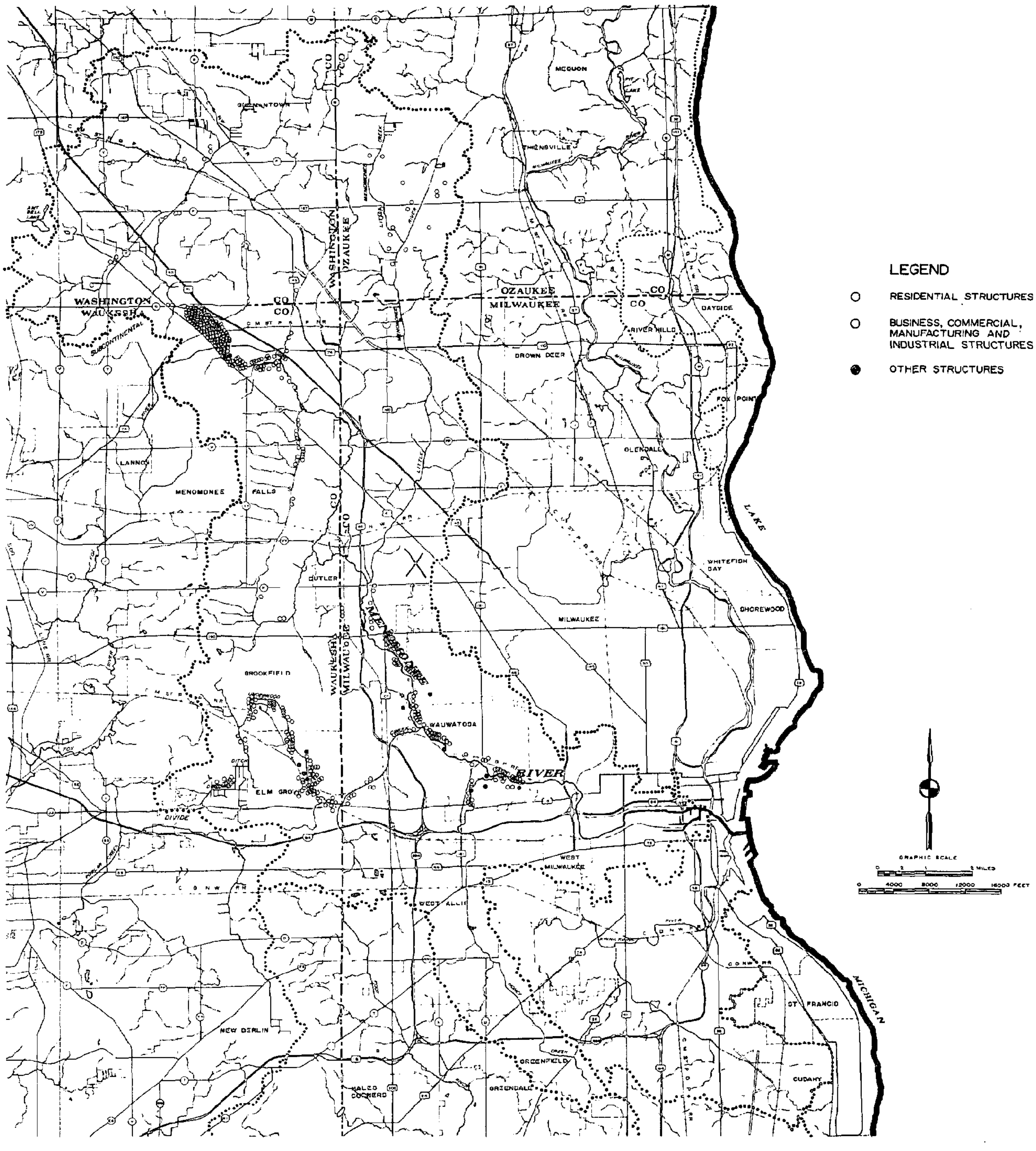
The historic flood information for the Menomonee River watershed, as obtained by means of the inventory efforts described above, is presented herein by major flood events. Major flood events are defined as those that caused relatively heavy widespread flooding, significant damage to property, and disruption of normal activities. Seven such events were identified beginning with the March 19, 1897 flood and extending through the April 21, 1973 flood. Although each major flood was of several days' duration, it is identified by the date on which the highest, or peak, flood stage was known or thought to have occurred. Selected information about each of the seven major flood events is presented in Table 33.

Within each account of a major flood, damage and disruption experienced along the main stem of the Menomonee River is discussed first, proceeding in the upstream direction, followed by descriptions of problems encountered along various tributaries. The flood problems discussed herein were selected so as to be representative of the kind of damage or disruption that occurred and of the locations in which it occurred. Monetary flood losses included in the descriptions of historic flooding are those reported or otherwise recorded during or shortly after each flood event and have not been adjusted to current economic levels. After describing the damage and disruption attributed to each flood, the meteorologic and hydrologic conditions prior to and during the flood are discussed. These descriptions include a review of antecedent moisture conditions as well as precipitation amounts and streamflows recorded during the event.

The format used for the April 21, 1973 flood—the last and most serious flood differs somewhat from the presentation used for the other six major floods. A large quantity of data and information is available for this flood, partly because it was the most serious flood event in the period of record in terms of the peak flood stage that occurred; partly because it occurred recently and its effects were readily and accurately recalled by observers; and partly because the Commission was conducting the Menomonee River watershed planning program at the time of the flood and was able to monitor the characteristics and effects of the event. Because so much information was obtained for the April 21, 1973 flood relative to other major floods, the data and information

Map 46

LOCATIONS OF FIELD INTERVIEWS CONDUCTED TO OBTAIN HISTORIC FLOOD INFORMATION AND STRUCTURE DATA IN THE MENOMONEE RIVER WATERSHED



After analyzing streamflow and flood stage records, reviewing newspaper accounts, examining historic information maintained by libraries and historical societies, and meeting with community officials, personal interviews were conducted with the owners or tenants of 485 structures in potential flood-prone areas of the Menomonee River watershed. The historic flood information assembled by this procedure has six potential applications in the watershed planning and plan implementation process: 1) identification and delineation of flood damage-prone areas; 2) determination of the cause of flooding and flood damage in those areas; 3) calibration of the hydrologic-hydraulic model; 4) computation of monetary flood risks; 5) formulation of alternative flood control measures; and 6) post-plan adoption, public information and educational activities.

Source: SEWRPC.

Figure 45

FORM USED TO INTERVIEW OWNER OR TENANT OF A STRUCTURE LOCATED NEAR A RIVER

FIELD SURVEY
of
STRUCTURE DATA AND FLOOD INFORMATION
for the
MENOMONEE RIVER WATERSHED PLANNING PROGRAM

INTERVIEWER:________________________ DATE:____________

(Take the following items into the field: topographic maps, low flight aerial photographs, folding rule, camera, hand level.)

STRUCTURE IDENTIFICATION:

1. Civil Division Name:__________ 2. Civil Division No.:__________ 3. Structure Identification No.:______

4. Address:________________________

5. Type:____Select from the following:
   - 1 single family residence
   - 10 two family residence
   - 20 multi-family residence
   - 30 mobile home
   - 40 residence under construction
   - 100 business-commercial
   - 200 manufacturing-industrial
   - 300 school
   - 400 church
   - 500 other public ____________
   - 600 other private ____________
   - 700 other ____________

6. Comments:________________________

INTERVIEWEE:

1. Name(s):________________________

2. No answer:__________ 2. Refused to cooperate:__________

4. *Comments:*________________________

STRUCTURE DATA:

1. Basement: Yes_____ No______

2. Vertical distance from yard grade to main entrance of structure to first liveable floor:__________

3. Estimated market value of structure and land excluding structure contents: $__________

4. Floodproofing measures available or in effect:__________

5. Comments:________________________

STRUCTURE IDENTIFICATION:

1. Civil Division Name:__________ 2. Civil Division No.:__________ 3. Structure Identification No.:______

FLOOD INFORMATION:

1. Event

a. *Date:*________________________

b. Water in basement?: ___Yes ___No_____Depth c. Water on first floor?:___Yes ___No ___Depth

d. Means by which water entered structure: _____ Select one or more of the following:

   1 *sanitary sewer back-up through floor drain, sink, etc.*
   2 cracks or other openings (other than floor drain or sump reservoir) in basement floor.
   3 cracks or other openings (other than windows) in basement wall.
   4 back-up through sump reservoir.
   5 overland flow through basement windows.
   6 overland flow through doorways.
   7 overland flow through first floor windows.
   8 other.____________

e. Floodproofing or protection measures used:__________

f. Peak stage relative to structure or other nearby reference point:__________

g. Type(s) of damage sustained including cost(s) if known:__________

h. Planimetric extent of surface inundation near structure: Shown on aerial photograph __________

i. Comments:__________

2. Event

a. Date:________________________

b. Water in basement?: ___Yes ___No ___Depth c. Water on first floor?: ___Yes ___No ___Depth

d. Means by which water entered structure:_____ Select one or more of the following:

   1 sanitary sewer back-up through floor drain, sink, etc.
   2 cracks or other openings (other than floor drain or sump reservoir) in basement floor.
   3 cracks or other openings (other than windows) in basement wall.,
   4 back-up through sump reservoir.
   5 overland flow through basement windows.
   6 overland flow through doorways.
   7 overland flow through first floor windows.
   8 other ____________

e. Floodproofing or protection measures used:__________

f. Peak-stage relative to structure or other nearby reference point:__________

g. Type(s) of damage sustained including cost(s) if known:__________

h. Planimetric extent of surface inundation near structure: Shown on aerial photograph __________

i. Comments __________

Source: SEWRPC.

Table 33

SELECTED INFORMATION ON MAJOR HISTORIC FLOODS IN THE MENOMONEE RIVER WATERSHED

Date[a]	Causative Event	Peak Discharge of the Menomonee River at Wauwatosa (cfs)[b]		Reaches Affected	Recurrence Interval of Instantaneous Flow in Years Assuming Existing (1975) Land Use-Floodland Development Conditions[c]
		Instantaneous	Daily		
March 19, 1897	Rainfall	--	--	Menomonee River downstream of Wisconsin Avenue, Milwaukee County.	--
June 22, 1917	Rainfall	--	--	Menomonee River downstream of confluence with Honey Creek, Milwaukee County. Honey Creek near State Fair Park, Milwaukee County.	--
June 23, 1940	Rainfall	--	--	Menomonee River in Milwaukee County. Little Menomonee River in Milwaukee County. Underwood Creek at Milwaukee-Waukesha County Line. Honey Creek in the Cities of West Allis and Wauwatosa, Milwaukee County.	--
March 30, 1960	Rainfall-Snowmelt	--	--	Menomonee River in Milwaukee and Waukesha Counties. Lilly Creek in the Village of Menomonee Falls, Waukesha County. Underwood Creek in the Village of Elm Grove, Waukesha County. Honey Creek in the City of West Allis, Milwaukee County.	--
July 18, 1964	Rainfall	6,010	2,870	Menomonee River in Milwaukee and Waukesha Counties. Lilly Creek in the Village of Menomonee Falls, Waukesha County. Underwood Creek at the Milwaukee-Waukesha County Line. Honey Creek in the Cities of West Allis and Wauwatosa, Milwaukee County.	7
September 18, 1972	Rainfall	6,610	2,520	Menomonee River above confluence with Underwood Creek in Milwaukee County. Underwood Creek in the Village of Elm Grove, Waukesha County and the City of Wauwatosa, Milwaukee County. Honey Creek in the City of West Allis, Milwaukee County.	9
April 21, 1973	Rainfall	13,500	6,380	Menomonee River in Milwaukee and Waukesha Counties. Lilly Creek in the Village of Menomonee Falls, Waukesha County. Underwood Creek in the City of Brookfield and Village of Elm Grove, Waukesha County and the City of Wauwatosa, Milwaukee County. Honey Creek in the Cities of West Allis, Milwaukee and Wauwatosa, Milwaukee County.	95

[a] *Flood events are identified by the day on which peak discharges and stages occurred.*

[b] *Streamflow records for the USGS gaging station on the Menomonee River at Wauwatosa (No. 04087190) begins on October 1, 1961.*

[c] *Based on the results of hydrologic-hydraulic simulation as described in Chapter IV, Volume 2, of this report.*

Source: SEWRPC.

are presented on a community basis rather than within the context of main stem and tributary summaries as was done with the other major floods. Furthermore, extensive illustrations are used to more fully describe the extent of inundation and the magnitude of the problems resulting from this most serious flood ever observed in the period of record.

Historic high water marks and flood stage profiles for more recent major floods, as well as for some minor floods, are on file in a reproducible form in the Commission offices. These profiles are among the best means of documenting in a detailed and definitive manner the severity of historic flooding by graphically presenting peak stages relative to the channel bottom and relative to various hydraulic structures located along many of the 72 miles of stream selected for development of detailed flood hazard information under the watershed study. All historic water marks were referred to Mean Sea Level Datum, 1929 Adjustment, so that the profiles of historic high water observations would be uniform with respect to the vertical reference employed. Where comparable historic high water marks are available, the data clearly indicate that the April 21, 1973 flood was the most severe in terms of the peak flood stages that occurred.

Some of the data used to reconstruct historic high water marks and flood stage profiles was obtained from staff and crest stage gages operated by the U. S. Geological Survey, the Milwaukee-Metropolitan Sewerage Commissions, the City of Milwaukee, and the Village of Menomonee Falls. Other data sources included high water marks measured by public officials, consulting engineers, and private citizens as well as April 21, 1973 flood stage data observed by the staff of the Regional Planning Commission.

Flood of March 19, 1897

The March 19, 1897 flood was the earliest major flood event of record within the watershed for which any significant amount of information was available,as indicated by the inventory of historic flood problems. This flood inundated areas along an approximately 1.7 mile reach of the Menomonee River—as shown on Map 47—beginning just north of Grand Avenue, now known as Wisconsin Avenue, and extending downstream into the industrial valley. The absence of reported flood damage elsewhere in the watershed probably reflects the fact that urban growth in the watershed had, as of the end of the last century, and with the exception of small settlements at Wauwatosa and Menomonee Falls, extended only as far west as what is now the Wisconsin Avenue crossing of the Menomonee River (see Map 9).

In the vicinity of Grand Avenue, floodwaters caused considerable damage to private residences, mostly occupied by brewery employees, milkmen, and railway shop workers located in a settlement having a population of about 600 people. The peak stage of the Menomonee River rose above the first and even the second floors of some of the houses. Floodwaters completely surrounded the shop of the St. Paul Railway Company which was located in the industrial valley and considerable economic loss was incurred.

According to a Milwaukee Journal account, the flood was caused by about 1.6 inches of rainfall on the afternoon and evening of Saturday, March 19. Considering the apparent severity of the resulting flooding, the relatively small volume of rainfall probably occurred under high antecedent moisture conditions that typically prevail in the late winter and early spring as a result of the snowmelt and rainfall processes.

Flood of June 22, 1917

As shown on Map 47, the flood of June 22, 1917, affected essentially the same areas as the less severe flood of March 19, 1897, and in addition caused problems farther upstream along the Menomonee River and along Honey Creek. The areas for which flood problems were reported correlated with the extent of urban development in the watershed which by 1917 generally extended as far west as State Fair Park.

The Menomonee River floodplain below what is now the Wisconsin Avenue viaduct was subjected to very serious flooding in that almost every resident was driven from the area. Nearly 50 people were rescued—some very young and others aged—from this area which had by this time acquired the name "Pigsville." According to the Milwaukee Journal:

> Many families have been hard hit by the flood, worst on record, not only losing their pigs and chickens but having their gardens washed away, their homes in some cases were damaged beyond repair. Coming down on the crest of the flood were baby buggies, bedsteads, wagon boxes and chicken coops, several with scared roosters and hens perched on top and numerous other things. Lodged under the Wells Street viaduct are two cottages which were torn from their foundations further up the river.

Farther downstream in the industrial valley, floodwaters stood two to six feet deep in the shops of the Chicago, Milwaukee, St. Paul and Pacific Railroad. Over 100 locomotives were stalled in the railroad yards and it was reported that the floodwaters picked up and moved a set of freight car trucks.

The Falk Corporation, located at its present site in the industrial valley immediately upstream of the 27th Street viaduct, was severely affected by the flood. All of the grounds as well as the interior of the buildings were covered with water resulting in damage to both machinery and stock. According to the account in the Milwaukee Journal, the Falk Corporation incurred about $200,000 damage to equipment and stock.

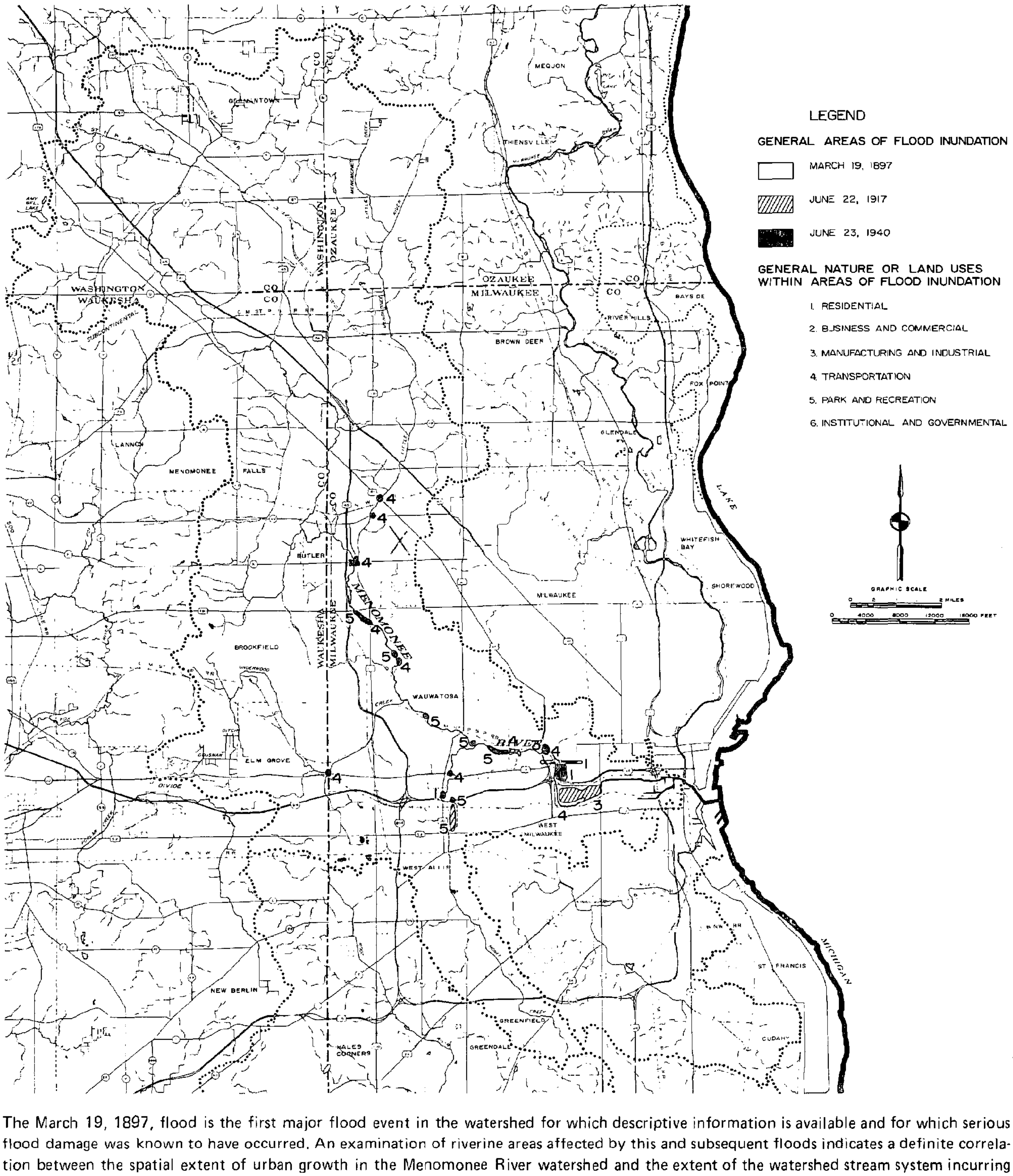
Other examples of flood damage were reported along the Menomonee River. For example, about $1,000 damage was incurred by the Grant Marble Company located in the industrial valley at the 27th Street viaduct. The Johns-Manville Company, located on W. State Street at N. 46th Street, reported a $25,000 loss as a result of the flood. As shown in Figure 46, considerable overland flooding occurred in what is now the City of Wauwatosa. Portions of Watertown Plank Road and Lovers Lane Road (now STH 100-Mayfair Road) were damaged by floodwaters. Along Honey Creek, State Fair Park was covered with more than two feet of water in some places. Street car service west of 37th Street was terminated because of a bridge washout over Honey Creek.

A total of 5.5 inches of rainfall occurred on Friday, June 22, 1917, and another 0.3 inches was recorded on the morning of June 23, giving a 24-hour total of 5.8 inches. This was the largest 24-hour rainfall amount recorded at Milwaukee Weather Bureau even to this date since 1870 when measurements first began. This volume of rainfall concentrated in a short time period would be expected to cause serious flooding.

It is interesting to note that the Milwaukee Journal account of the June 1917 flooding in the lower Menomonee River watershed makes explicit reference to the

Map 47

FLOOD PROBLEM AREAS IN THE MENOMONEE RIVER WATERSHED FOR THE MARCH 1897, JUNE 1917, AND JUNE 1940 FLOODS



The March 19, 1897, flood is the first major flood event in the watershed for which descriptive information is available and for which serious flood damage was known to have occurred. An examination of riverine areas affected by this and subsequent floods indicates a definite correlation between the spatial extent of urban growth in the Menomonee River watershed and the extent of the watershed stream system incurring flood damage and disruption. The primary cause of flooding as a serious problem within the watershed has been failure to adjust and adapt land use in floodland areas to the natural floodwater conveyance and storage function of those areas.

Source: SEWRPC.

Figure 46

FLOODING OF 68TH STREET IN THE CITY OF WAUWATOSA: JUNE 1917

Taken during the height of the June 1917 flood, this photograph shows the 68th Street crossing of the Menomonee River as seen from the north side of the river looking south along 68th Street. Extensive overland flooding, similar to that which occurred in April 1973, is evident in this part of Wauwatosa.

Source: Mr. George Raasch.

potential impact of land use on flood problems. According to that article, intensive urbanization attendant to expansion of the metropolitan areas resulted in a reduction in the floodwater storage capacity of the land, and the installation of storm sewers and improvements to drainage channels increased runoff rates, the combined effect of which was to generate more runoff in less time thereby producing increased flood discharges and stages in the lower watershed. This discerning observation was made over 50 years ago at a time when, as shown on Map 9, only slightly over 10 percent of the watershed area had been urbanized.

Flood of June 23, 1940

Another major flood within the watershed occurred on June 23, 1940. This event apparently approached but did not equal the severity of the June 22, 1917 flood—inundating and causing damage to areas primarily along the Menomonee River with scattered occurrences of flooding also reported along Honey Creek, Underwood Creek, and the Little Menomonee River. The spatial distribution of the areas affected by this flood event is shown on Map 47, which indicates that some of the problem areas were located west and north of the limits of urban development as of 1940 as shown on Map 9. The occurrence of reported flood problems outside of the urban area is attributable to the fact that the rural area problems consisted primarily of damage to and the closing of river crossings and riverine area roadways.

The residential area—"Pigsville"—located near the Menomonee River at what is now Wisconsin Avenue once again suffered major flood damage. According to the Milwaukee Journal, "The muddy river surged over its banks and swirled along the streets and sidewalks." Basements were flooded by sewer backup and overland flow and some cars were inundated to window level.

Further upstream, high and rapidly moving floodwaters destroyed part of a brick building located at N. 46th Street and W. State Street in the City of Milwaukee. About one mile upstream in Jacobus Park in the City of Wauwatosa, the Menomonee River damaged stone embankments along the channel, overtopped roadways, and destroyed recently completed landscaping including newly planted trees. Sandbags were placed at the 68th Street bridge, which is located near the upstream end of Jacobus Park, to prevent its collapse.

Further upstream in Wauwatosa, floodwaters covered that City's Hart Park, a two-block area containing a football field, a baseball field, and tennis courts. Trees and shrubs were uprooted in this area and carried away. About two feet of water covered the floor of the pavilion in Hoyt Park, a Milwaukee County Park partly contained in the Menomonee River floodlands upstream of the village area in Wauwatosa.

The Menomonee River Parkway Drive was inundated at several locations upstream of Hoyt Park, as were portions of the Milwaukee County golf course in Currie Park as shown in Figure 47. Menomonee River floodwaters undermined the abutments of the Mayfair Road (STH 100) Bridge in the City of Wauwatosa adjacent to Currie Park and, as a result, the Bridge was closed to traffic. Near the confluence of the Menomonee and Little Menomonee Rivers in the City of Milwaukee, rising floodwaters forced the closure of short segments of Mayfair Road (STH 100) and W. Hampton Avenue, both of which have since been rebuilt at higher grades in this area.

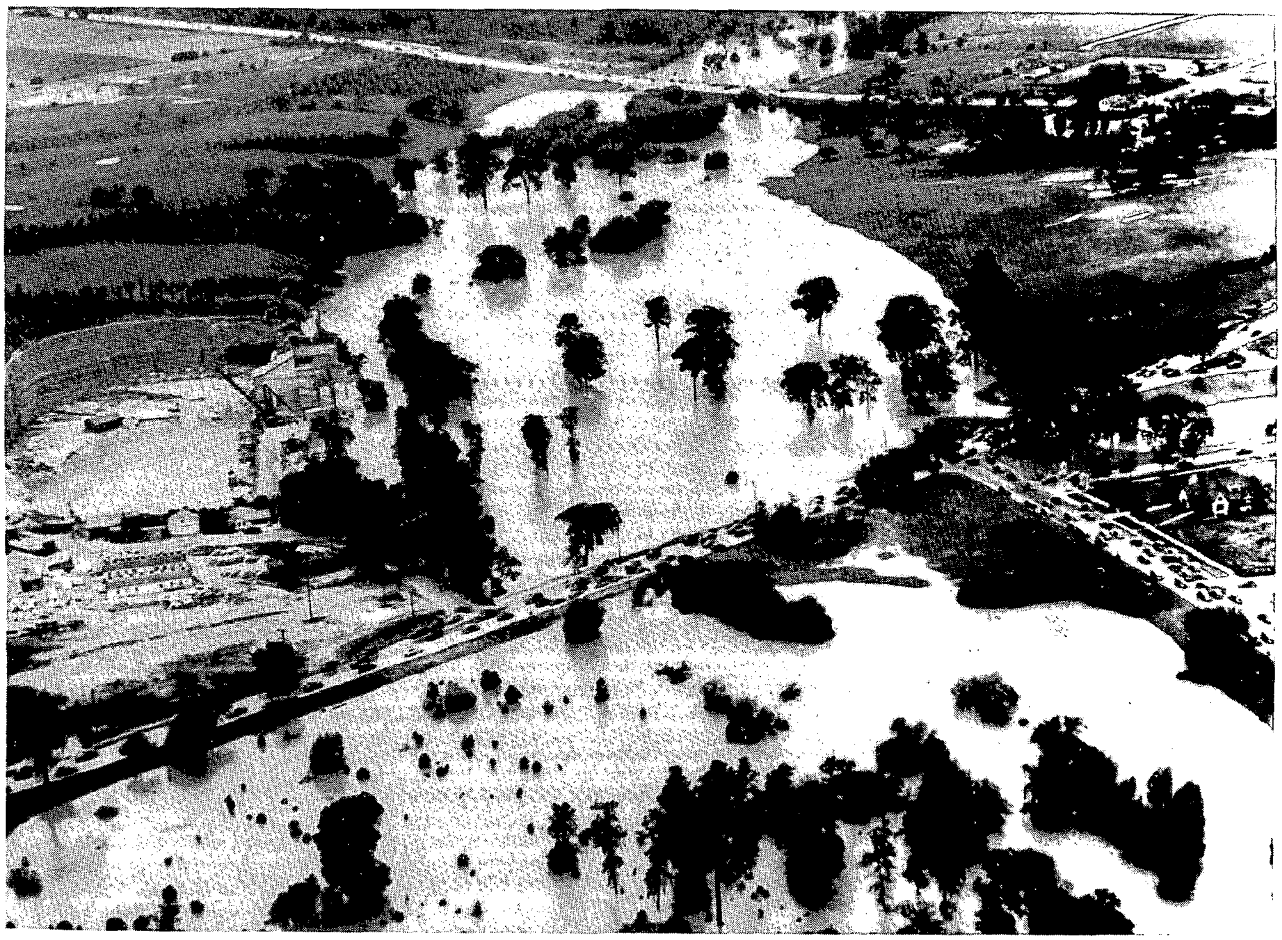
While there were no further flood problems reported along the Menomonee River upstream of its confluence with the Little Menomonee River, road closings were reported along the latter in Milwaukee County at W. Silver Spring Drive and at W. Appleton Avenue (USH 45), both of which have been reconstructed at higher grades since 1940. At the Milwaukee-Waukesha County Line, Underwood Creek flowed onto and closed a segment of W. Bluemound Road (USH 18).

Numerous problems were reported along the reach of Honey Creek that passes through the Cities of West Allis and Wauwatosa. A boy drowned in West Allis when he lost his balance in the rapidly moving waters of Honey Creek and was swept downstream. Many basement floodings were reported in West Allis; the 84th Street bridge in Milwaukee over Honey Creek was washed out; and farther downstream, W. Bluemound Road (USH 18) was flooded to a depth of about one foot.

The June 1940 flooding in the Menomonee River watershed resulted from rainfall amounts in the four to six inch range occurring over a period of several days. The Menomonee River watershed storm was one part of widespread rainfall occurring throughout much of southeastern Wisconsin during the four-day period of June 21 to June 24, 1940. The recorded rainfall totaled 5.97 inches at the Milwaukee National Weather Service office located just south of the watershed while 5.88 inches were mea-

Figure 47

FLOODING OF CURRIE PARK IN THE CITY OF WAUWATOSA: JUNE 24, 1940



This photograph, taken on June 24, 1940, shows the Menomonee River occupying its natural floodplain in the Currie Park area in the City of Wauwatosa. STH 100, shown in the photograph, later had to be closed to traffic due to the results of this summer flood.

Source: The Journal Company.

sured west of the watershed at Waukesha in Waukesha County and 4.22 inches were observed northeast of the watershed at Port Washington in Ozaukee County. Northwest of the watershed at West Bend in Washington County, rain began on Saturday, June 22, and lasted for three days through Monday, June 24, during which time 5.42 inches were recorded. Most of the rainfall associated with the June 1940 flood occurred on Saturday, June 22, in that 60 to 75 percent of the rainfall recorded at each of the above four stations occurred on that date.

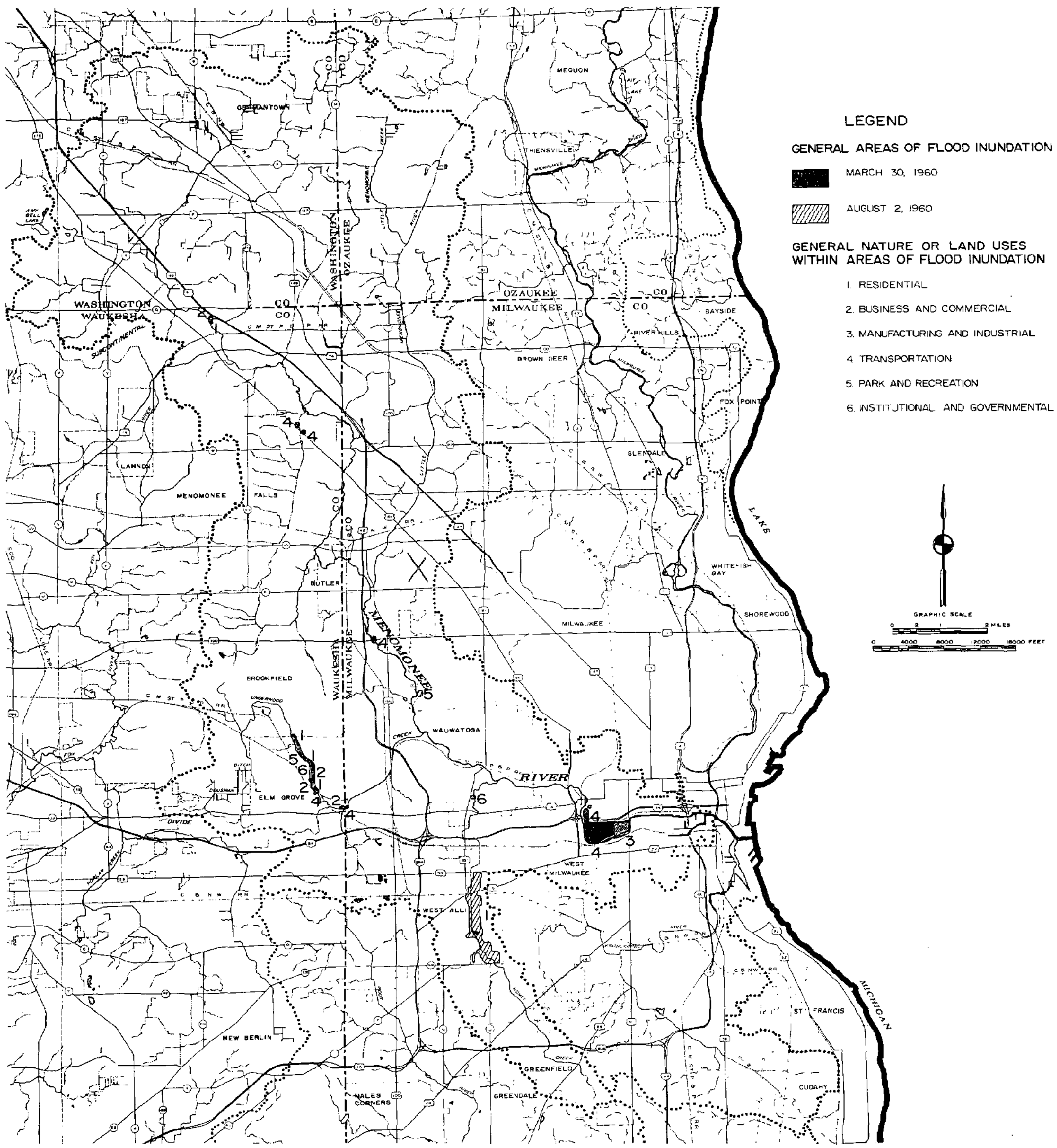
Flood of March 30, 1960

Exceeding the severity of the June 22, 1917 flood, the March 30, 1960, snowmelt-rainfall event caused widespread damage to low-lying areas along the Menomonee River in Milwaukee and Waukesha Counties and along Underwood Creek in Waukesha and Milwaukee Counties. Riverine areas affected by the flood are shown on Map 48 which, when compared to the urban growth map included as Map 9, again indicates a close correlation between the flood damage areas and the extent of urban development as of 1960. While the damage resulting from previous major floods had been concentrated in the Milwaukee County portion of the watershed, the March 1960 flood, in addition to causing damage in Milwaukee County, caused serious problems to the west and north in the Waukesha County Villages of Elm Grove and Menomonee Falls. This is primarily attributable to the extensive urbanization that occurred in the watershed between about 1940 and 1960 creating, in turn, additional flood damage-prone areas.

Flood inundation and damage in the Menomonee River industrial valley were extensive; large areas were inundated and high monetary flood damages occurred. The U. S. Department of Agriculture, Soil Conservation Service, assessed flood damages in the Menomonee River watershed for the March 1960 flood and reported these

Map 48

FLOOD PROBLEM AREAS IN THE MENOMONEE RIVER WATERSHED FOR THE MARCH AND AUGUST 1960 FLOODS



Major floods are random events and therefore it is possible, although improbable, to have two major floods occur within a watershed in a single year such as occurred in 1960 in the Menomonee River watershed. The March 30, 1960, flood was the first major flood event in which serious flood damages occurred in the Waukesha County portion of the Menomonee River watershed. Widespread inundation and extensive damage also occurred in the Menomonee River industrial valley as a result of the March 30, 1960, flood. The August 1960 flood also caused serious flood damage within the watershed.

Source: SEWRPC.

to be $2,950,000.[2] Included among these estimated flood damages were damages to 12 houses in Menomonee Falls, damage to several houses in the vicinity of the W. Wisconsin Avenue viaduct, and damages to industrial plants in the lower valley. The latter area was indicated as the predominant area of damage in 1960.

The Thiele Tanning Company, which is located in the industrial valley near the 27th Street viaduct, experienced flooding to a depth of two feet and incurred extensive damage. At the Falk Corporation plant the Menomonee River flowed onto its floodplain, entered the Falk property from the west end, and crested at an elevation of about 589.7 feet above Mean Sea Level Datum, or from four to seven feet above the grades of the land surrounding the buildings and the first floors within the buildings. The Menomonee River did not overtop the earthen dike paralleling the river on the south side of the Falk property although it did rise to within about one foot of the top of the dike. As shown in Figure 48, floodwaters completely surrounded the Falk Corporation facilities and, as a result of overland flow and sewer backup, the interior of the plant was flooded. All the flooded equipment was covered with fine silt or dust, and it was necessary to dismantle, clean, and reassemble the electrical and mechanical machinery. Three weeks passed before even part of the plant was back in operation. As an indication of the magnitude of the post-flood clean-up operation, to restore electrical equipment required the services of three 125-man shifts of electricians for a period of three weeks. The June 1960 peak stage at the Falk Corporation facility was about one foot higher than that recorded in 1917—the previously largest flood of record in this area. Although the Falk Corporation, which is located immediately upstream of the 27th Street viaduct, is only about two miles from the mouth of the Menomonee River, the peak stage at the plant was approximately 8.0 feet above the level of Lake Michigan as recorded in the harbor. Many automobiles and trucks were stranded in the parking lot with water rising to within a foot of the roofs. The water rose so rapidly and became so deep that boats were required to rescue about 25 night-shift workers early on Wednesday, March 30.

As a result of the approximately $1.3 million monetary loss incurred by the Falk Corporation, extensive flood control measures were subsequently taken by the company including construction of a concrete floodwall—with movable gates at the railroad tracks—along the west end of the property and a sheet pile floodwall along the Menomonee River on the south side of the Falk property and along the east edge of the grounds. These works, in combination with a concrete wall on the north that existed prior to the 1960 flood, have prevented inundation of the plant and grounds in subsequent floods, one of which—the April 1973 flood—peaked about two feet higher at the Falk plant than the March 1960 flood. The Chicago, Milwaukee, St. Paul and Pacific Railroad yards and engine shops which are located in the industrial valley also flooded, with up to one foot of water being reported within the shops. Water entered over the railroad track embankment at the northwest corner of the property and moved in an easterly and southeasterly direction inundating much of the complex—both the grounds and the buildings—to depths ranging from about one-half to two feet. The floodwaters damaged electrical machinery, eroded ballast and other loose materials, and carried railroad ties downstream. After the March 1960 flood, the Milwaukee-Metropolitan Sewerage Commissions constructed a sheet pile floodwall along the east bank of the Menomonee River at the west edge of the railroad property and also deepened and widened the channel. The Chicago, Milwaukee, St. Paul and Pacific Railroad constructed a 3,000-foot-long earthen dike along the south limits of the railroad property extending from the downstream terminus of the sheet pile floodwall to the upstream end of the Falk Corporation floodwall. The sheet pile floodwall and the earthen dike, in combination with the protection provided by similar flood control works at the Falk Corporation, have prevented inundation of the railroad yards from subsequent floods including the severe April 1973 flood.

No major damage was reported farther upstream in the residential area near the W. Wisconsin Avenue crossing of the Menomonee River which was the site of extensive damage during earlier floods such as those that occurred in March 1897, June 1917, and June 1940. Such scattered examples as flooded basements, closed roadways, and stranded motorists were reported but these were minor compared with the damage caused by preceding flood events. The cessation of flood problems in that area was primarily attributed to the extensive channel improvements from N. 43rd Street to N. 45th Street, initiated in 1940 as a Works Project Administration project, and to previously completed work on a section of the Menomonee River immediately downstream extending from N. 43rd Street to the present East-West Freeway. These modifications consisted of channel straightening, widening and lowering, and the placement of masonry sidewalls.

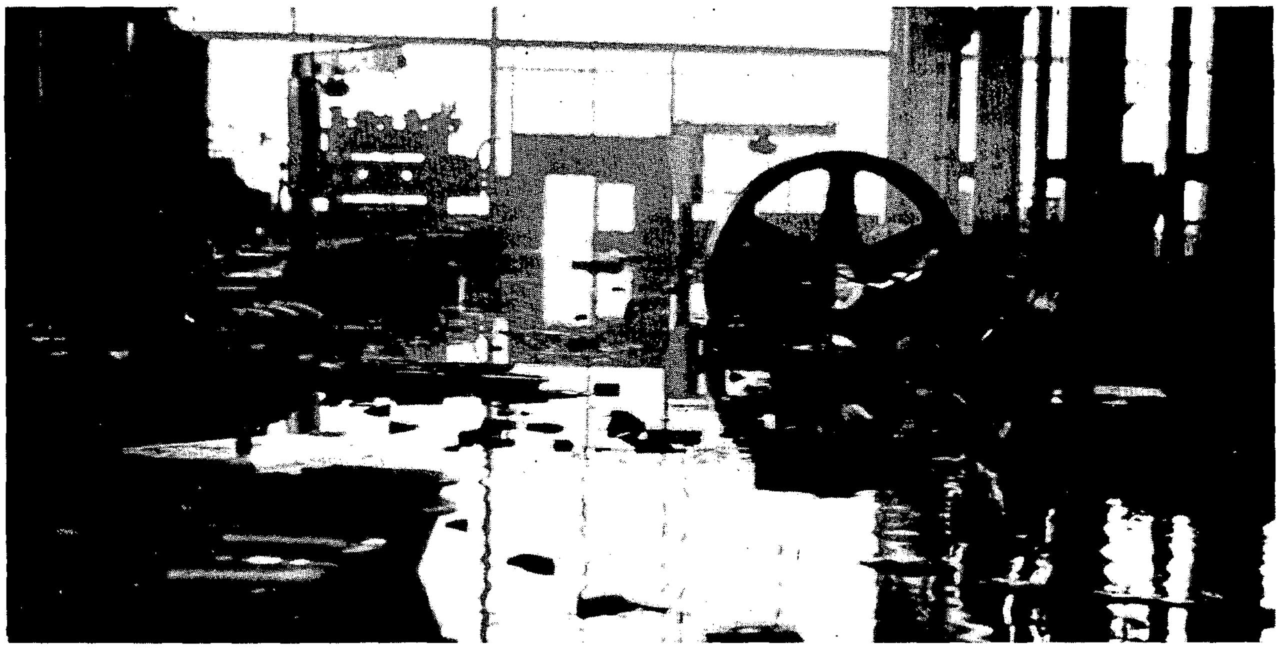
No serious flood problems were reported farther upstream along the Menomonee River in the City of Wauwatosa except at the W. Capitol Drive crossing of the River. At this location, low segments in W. Capitol Drive at and west of the River were inundated, trapping cars and their occupants. Subsequent reconstruction of the USH 45 and W. Capitol Drive intersection has reduced the likelihood of similar roadway flooding in this area.

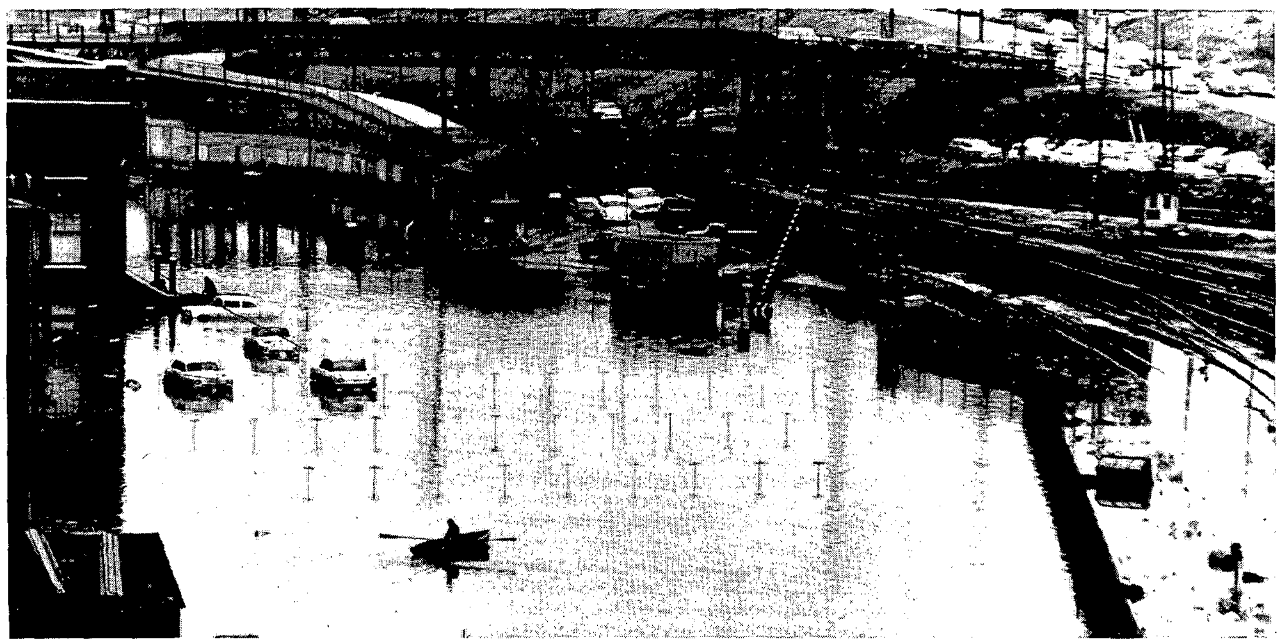
Scattered examples of nuisance flooding occurred along the Menomonee River in the Village of Menomonee Falls. Reported problems included overland and basement flooding west of the River along Grand Avenue near the north end of the Village. In addition, just east of this location across the River, floodwaters covered the parking lot and rose almost to the top of the loading dock of the River Court Shopping Center but did not enter the building. A part of W. Appleton Avenue was closed near

[2] *"Report for Flood Control in the Milwaukee River Watershed," U. S. Department of Agriculture, Soil Conservation Service, February 1961.*

Figure 48

FLOODING OF THE FALK CORPORATION PLANT IN THE MENOMONEE RIVER INDUSTRIAL VALLEY: MARCH 1960





The March 1960 flood on the Menomonee River caused extensive damage to industrial land uses. Water up to seven feet deep covered most of the machinery in the large Falk Corporation plant in the City of Milwaukee, and boats were required to rescue night shift workers. In addition to the high costs of cleanup, machinery repair and replacement, and structural damage repair, the industrial flood losses included the loss of wages and profits due to the extended halt in production caused by the flooding. In a complex metropolitan economy, the economic losses associated with such a halt in production are felt in areas far removed from the location of the flooded industry.

Source: The Journal Company.

its crossing of Lilly Creek, and road shoulders were washed out farther north near Lilly Road. According to newspaper accounts, the City of Brookfield had little flooding, although frozen culverts caused some melted snow to back up and temporarily pond in the streets.

Serious flooding occurred along Underwood Creek in the Village of Elm Grove with inundation and damage being reported along a 1.7-mile long reach extending from the Milwaukee-Waukesha County Line upstream to the north end of Village Park. At the downstream end of this reach, water from Underwood Creek flowed over and closed W. Bluemound Road (USH 18) and also overtopped small bridges that span the creek and provide access to several business establishments.

The Village business district, which is clustered around the intersection of Watertown Plank Road and Underwood Creek, was severely damaged by the March 1960 flood. The rapidly moving high water damaged the Elm Grove Printing Shop and overtopped the Watertown Plank Road, stranding cars and causing a temporary road closure. The Elm Grove Fuel and Supply Company, which was located on the west side of the creek just north of Watertown Plank Road, incurred heavy damage as a result of basement flooding, the loss of lumber which floated downstream, and the tipping of one oil storage tank. Reinders Brothers Garden Fair and Feed Mill, located on the other side of the creek, also incurred extensive flood damage. The lower warehouse floor was inundated by as much as 41 inches of water, damaging both stock and milling machinery. Farther upstream at Juneau Boulevard, floodwaters were over three feet deep in the garage of Safeway Transport Company and some of the buses were damaged.

The Village Hall, which at the time of the March 1960 flood was located on the west side of Underwood Creek just south of Juneau Boulevard, was flooded to a depth of three feet over the first floor. A boat was used to move files and other records from the Village Hall to emergency quarters. Damage also occurred in the residential areas north and south of Juneau Boulevard and east of Underwood Creek. This flooding consisted primarily of basement and lower floor inundation brought about by overland flooding and sewer backup. There was no flooding reported along Underwood Creek upstream of the Village of Elm Grove.

Serious flooding occurred along Honey Creek in West Allis as a result of the March 1960 flood and then again later that year in early August. While the March 1960 flooding in West Allis was part of a watershed-wide event, the August 3, 1960, flood was limited to the Honey Creek subwatershed. In both of these floods, basements were flooded along Honey Creek and in some instances basement walls collapsed as a result of high external hydrostatic pressure. Figure 49 shows the extent of overland flooding and sewer backup along Honey Creek in West Allis as a result of the March 1960 flood. One instance of Honey Creek flooding was reported in March 1960 downstream in the City of Wauwatosa. Floodwaters entered the gymnasium and boiler room at St. Jude the Apostle grade school located on the west bank of Honey Creek just north of W. Wisconsin Avenue.

In February 1967, the Metropolitan Sewerage Commission of Milwaukee County completed construction of a 2.14 mile long, large underground conduit in West Allis to carry Honey Creek flows from McCarty Park downstream to and under the East-West Freeway (IH 94) within the City of Milwaukee. As a result of the construction of that conduit, which has sections composed of parallel concrete box culverts, parallel arch pipe and tunnel, there have been no serious instances of flooding reported along Honey Creek in West Allis.

A critical combination of rainfall and snowmelt was responsible for the March 1960 flood in the Menomonee River watershed. There were 24 inches of snow on the ground at Milwaukee on March 4, the third largest snowpack that has been recorded to that date at Milwaukee. By March 27, about six inches of snow cover remained on the watershed based on the measurements made at the Milwaukee National Weather Service office. Unusually low subfreezing temperatures persisted during the first 26 days of March, with the average daily temperatures being 26.6°F. Temperatures rose sharply on Sunday, March 27, with a maximum of 46°F recorded at Milwaukee on that day, and maximum temperatures of 41°F, 62°F, and 52°F were reached on March 28, March 29, and March 30, respectively. This accelerated the melting of the snow cover.

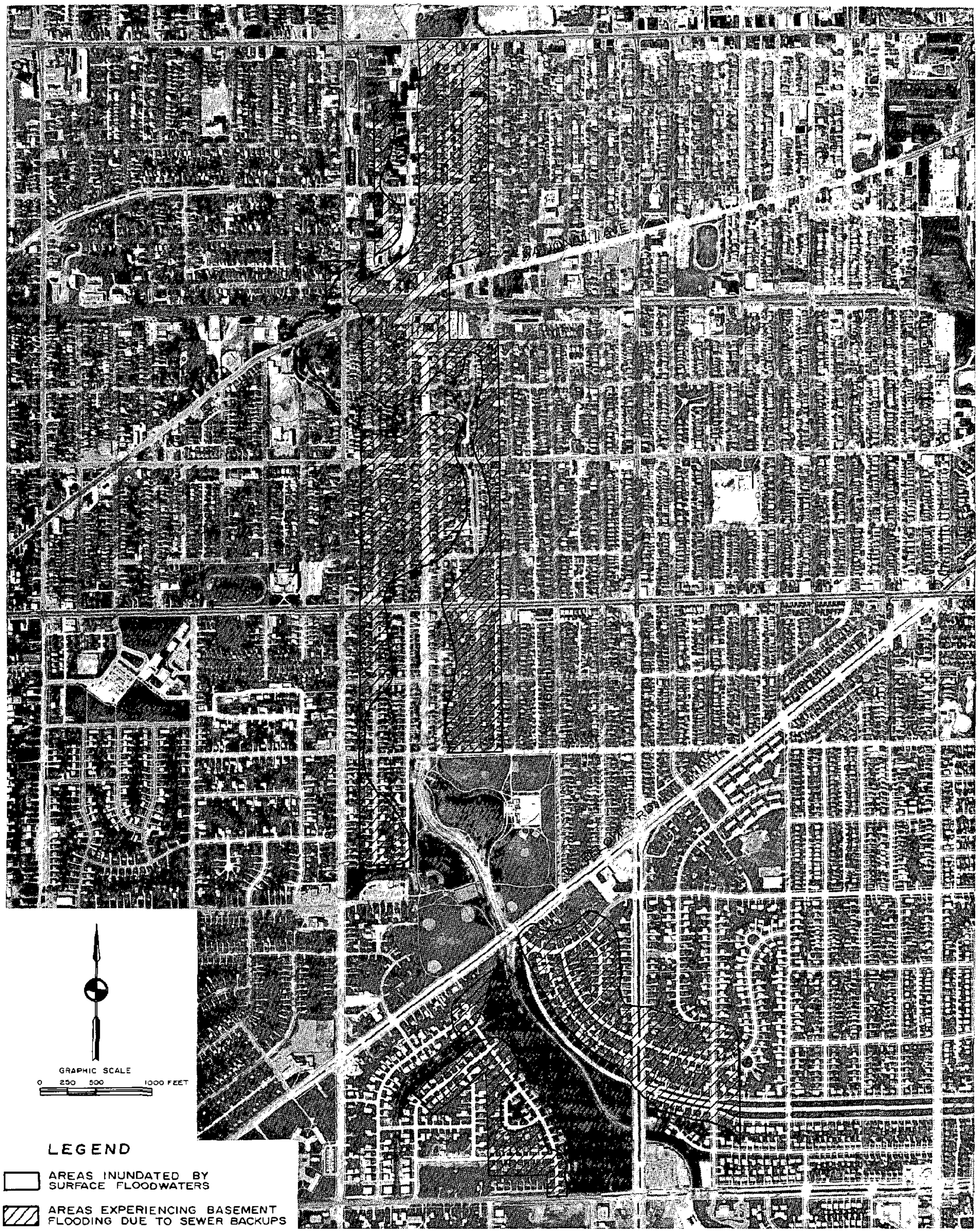
Precipitation began over the watershed at approximately 9 p.m. on Tuesday, March 29, the third day of the thaw, and continued through Wednesday, March 30. During this two-day period 2.57 inches of rainfall were recorded just south of the watershed at the Milwaukee station, and 1.32 inches, 2.22 inches, and 2.63 inches were measured in the watershed at the Village of Germantown, Mt. Mary College in Milwaukee, and in the City of West Allis, respectively. A large proportion of this rainfall probably appeared as direct runoff in the streams since it fell either on snow cover or on soil still frozen or saturated with water as a result of the melting snow cover. Direct runoff from the rainfall, occurring in combination with the direct runoff generated by melting of the watershed snow cover, produced flows in excess of channel capacity. The floodwaters flowed onto the natural floodplains causing widespread damage in the lower portion of the watershed.

<u>Flood of July 18, 1964</u>

The flood of July 18, 1964, resulted from two days of widespread heavy rainfall. As shown on Map 49, flood damage in the Menomonee River watershed was not so extensive as in earlier major floods, being limited primarily to scattered nuisance situations along the Menomonee River and more serious flooding along Honey Creek primarily in the City of West Allis. Flood problems were confined to the urban portion of the watershed, and no serious agricultural flood damages were reported.

Figure 49

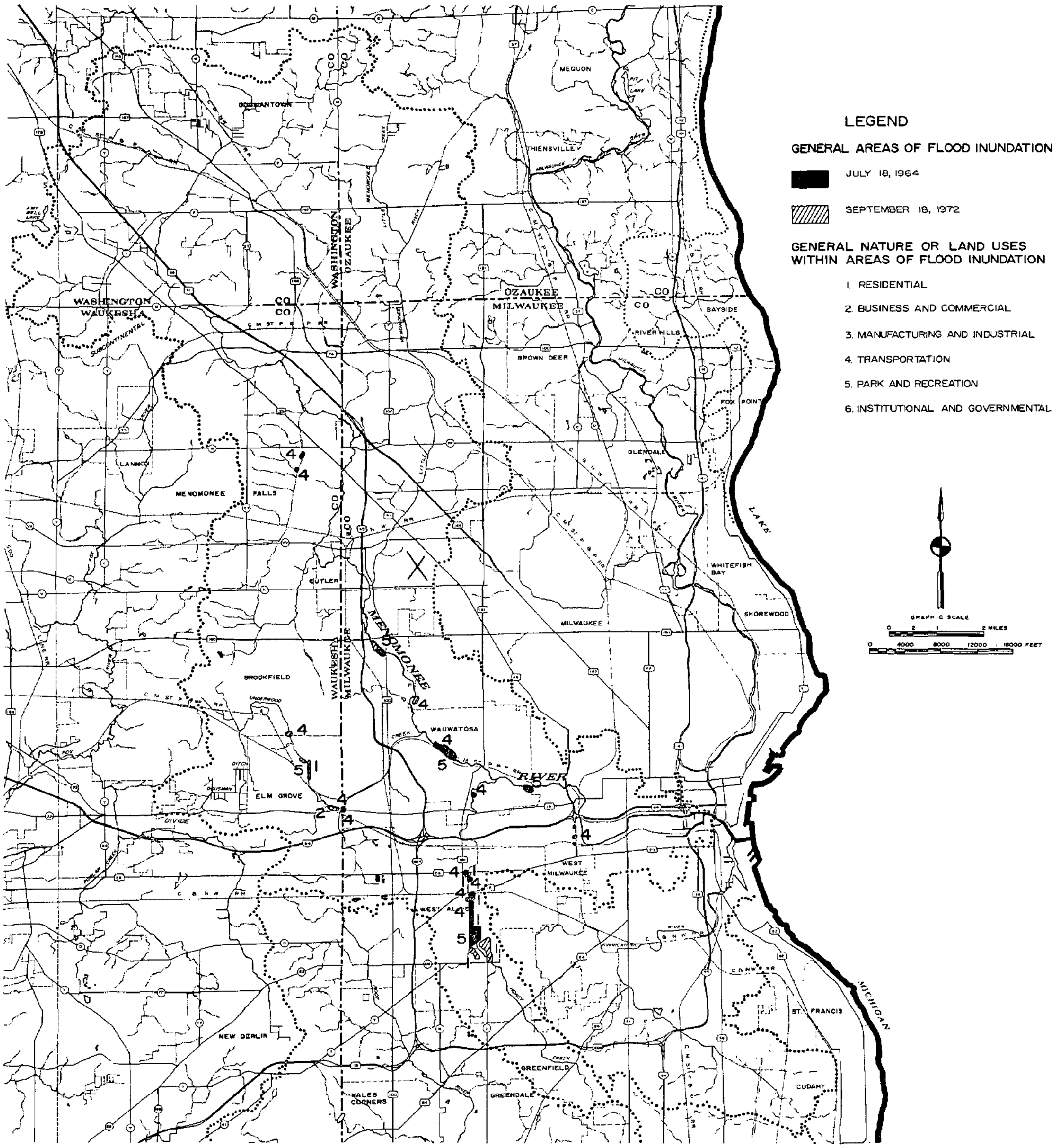
AREAS INUNDATED BY THE MARCH 1960 FLOOD EVENT ALONG HONEY CREEK IN THE CITY OF WEST ALLIS



Source: City Engineer, City of West Allis.

Map 49

FLOOD PROBLEM AREAS IN THE MENOMONEE RIVER WATERSHED FOR JULY 1964 AND SEPTEMBER 1972 FLOODS



The July 1964 and September 1972 flood events were similar in that both produced instantaneous peak discharges at the N. 70th Street crossing of the Menomonee River watershed of between 6,000 and 7,000 cubic feet per second and both caused flood problems in the lower reaches of the watershed. The two floods were, however, caused by markedly different rainfall events. The July 1964 flood was caused by a rainfall which averaged over 6 inches but which occurred after a period of very dry weather.,The September 1972 flood was caused by a rainfall which averaged only about 2.75 inches but which occurred under high antecedent moisture conditions. Thus, while the seriousness of a flood event is certainly influenced by the amount, intensity, and spatial distribution of rainfall, the antecedent moisture conditions also markedly influence the resulting flood flows and associated damage and disruption.

Source: SEWRPC.

Firemen rescued two boys in Jacobus Park in the City of Wauwatosa who were floating down the River and became trapped in the limbs of a tree. A problem was reported farther upstream near Hoyt Park in the City of Wauwatosa where the Menomonee River flowed onto the parkway drive and interfered with traffic flow. Two cars were trapped in the railroad underpass on Swan Boulevard immediately west of the Menomonee River, and about 35 acres of the Currie Park Golf Course were inundated. At W. Capitol Drive, several cars were trapped in a railroad underpass west of the Menomonee River. After the floodwaters receded, the body of a drowning victim was found in a car at this location.

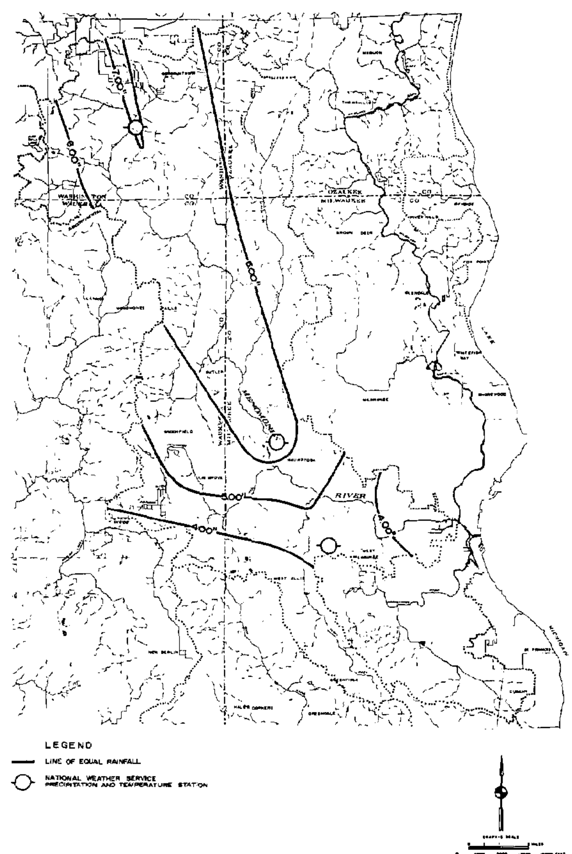
Lilly Creek, a Menomonee River tributary in Menomonee Falls, overflowed its banks and temporarily closed short segments of several streets. The only problem reported along Underwood Creek occurred at the Waukesha-Milwaukee County Line where floodwaters from the Creek inundated W. Bluemound Road. The West Allis portion of the Honey Creek subwatershed experienced damage, while less serious problems were reported near the downstream end of Honey Creek in the City of Wauwatosa. West Allis police reported about 50 complaints of flooded basements. High waters closed five streets that crossed a 0.9 mile long reach of Honey Creek extending from McCarty Park downstream to W. Hicks Street and also closed W. Greenfield Avenue farther downstream. A bridge in McCarty Park was washed out, and carried over three blocks where it passed through the W. Arthur Avenue bridge and continued downstream. A boy fell into Honey Creek several blocks upstream of State Fair Park but was rescued by firemen. Farther downstream in the City of Wauwatosa, Honey Creek left its banks along a reach in the vicinity of W. Wisconsin Avenue, flowed onto the local streets, and caused basement flooding.

The July 1964 flooding in the Menomonee River watershed resulted from widespread rainfall that occurred throughout the seven-county Southeastern Wisconsin Region on Saturday and Sunday, July 17 and 18. Recorded rainfall amounts at the 17 stations existing in the Region at that time, and for which observations were published by the National Weather service, ranged from a low of 1.28 inches at Whitewater in western Walworth County to a high of 7.25 inches at West Bend in Washington County and had a median value of about 2.6 inches. The storm event was focused on the Menomonee River watershed in that three of the four largest rainfall measurements were made in the watershed. Two-day totals of 7.05 inches, 6.37 inches, and 4.19 inches were recorded respectively, at the Village of Germantown in the watershed headwaters, at Mount Mary College in the middle portion of the watershed, and in the City of West Allis in the lower reaches of the watershed. Map 50 shows the spatial distribution of the July 17 and 18 rainfall as constructed from rainfall amounts reported at National Weather Service stations in and near the watershed. Based on a Thiessen polygon analysis, the average rainfall over the watershed was 6.16 inches. The estimated recurrence interval of the recorded rainfall, which appears to have occurred over a period of about 24 hours, is about 100 years indicating that the entire watershed was subjected to a very severe storm.

The July 18, 1964, flood is the first major flood event for which daily streamflow gaging records were available since the gage on the Menomonee River (USGS Gage No. 04087120) was placed in operation on October 1, 1961, about 1 1/2 years after the serious flood of March 1960. Using recorded Menomonee River flows at Wauwatosa as shown in Figure 50, the direct runoff from the July 1964 flood was determined to be 2.16 inches, the third largest runoff volume recorded at that location during the 12 water years of record from 1962 through 1973. Figure 50 also indicates that the peak daily flow for the flood was 2,870 cfs which occurred on Saturday

Map 50

RAINFALL OF JULY 17-18, 1964, OVER THE MENOMONEE RIVER WATERSHED

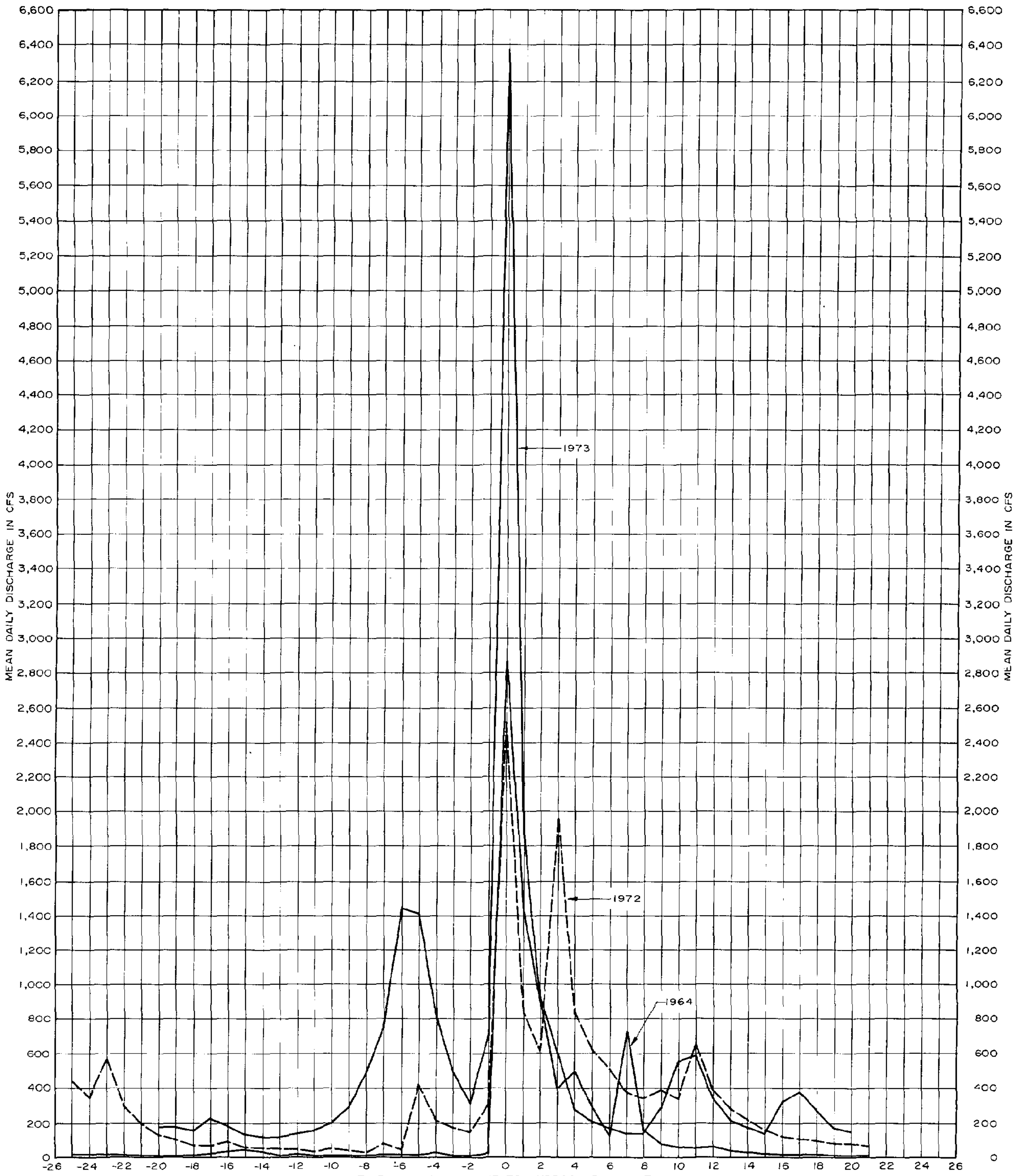


The July 1964 flood was caused by a very severe rainstorm which caused over six inches of rain to fall on the watershed over a two-day period. Fortunately, as a result of unusually dry antecedent conditions, only about 35 percent of the heavy rainfall appeared as direct runoff; otherwise the ensuing flooding would have been much more serious.

Source: SEWRPC.

Figure 50

HYDROGRAPHS OF SELECTED MAJOR FLOODS ON THE MENOMONEE RIVER AT WAUWATOSA



Source: SEWRPC.

July 18; while the instantaneous peak discharge, which also occurred on that day, was 6,010 cfs and had a recurrence interval of about seven years. The instantaneous peak discharge was the third largest measured at the gaging station during the 12-year period of record from 1962 through 1973, while the daily peak discharge was the second largest.

It was fortunate that only 35 percent of the 6.16 inch average rainfall appeared as direct runoff, otherwise the ensuing flooding would have been more serious. The low percentage of direct runoff relative to the unusually large amount of rainfall is primarily attributable to the very dry weather conditions preceding the July 18, 1964 flood. During June 1964, for example, total precipitation amounts recorded at the three in-watershed stations varied from only about 30 to 50 percent of normal. These dry-weather conditions persisted into July in that total precipitation amounts recorded at the three stations during the first half of July ranged from about 40 to 90 percent of normal. These dry antecedent moisture conditions favored interception, depression storage, and infiltration of the rainfall, thereby reducing the volume of direct runoff as well as the magnitude of the peak flow. If the July 1964 flood had occurred under wet antecedent conditions, it probably would have been the most severe flood to ever occur in the watershed.

Flood of September 18, 1972

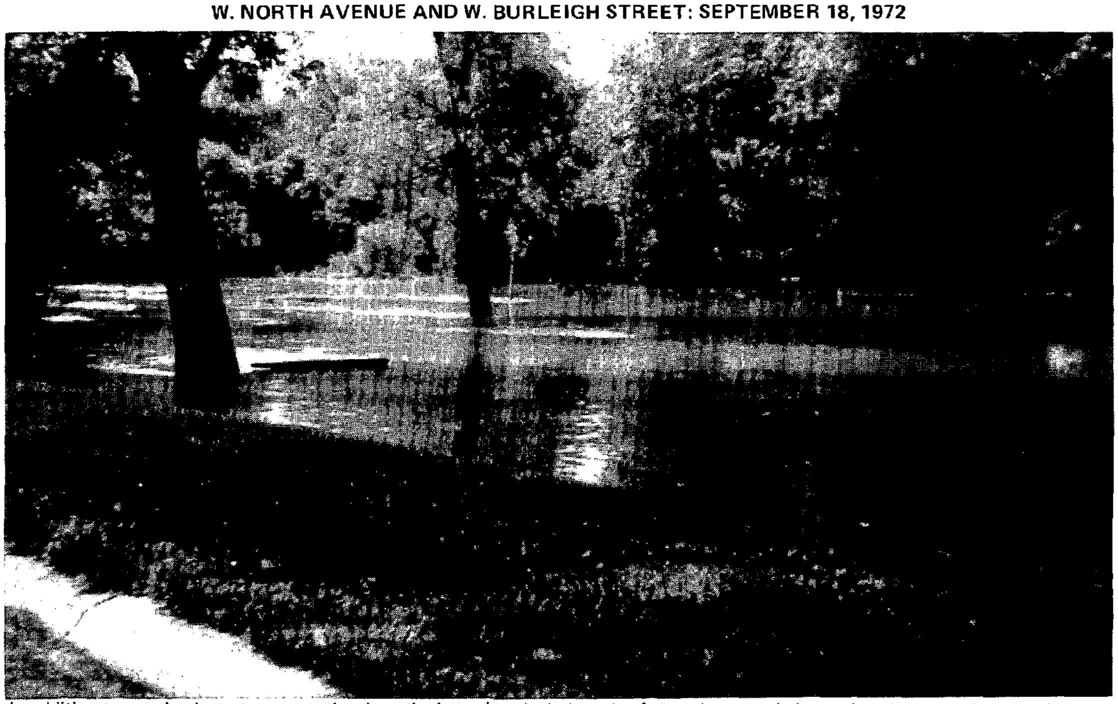
As shown on Map 49, the late summer flood of September 18, 1972, which was caused by a relatively large quantity of rainfall occurring under high antecedent moisture conditions, affected the main stem of the Menomonee River and the area along Honey Creek in Milwaukee County and low-lying areas along Underwood Creek in the Village of Elm Grove and the City of Wauwatosa. Problems resulting from the flood consisted primarily of closed roadways and flooded basements and were confined primarily to urban areas with no serious agricultural flood damages being reported.

During this flood the River inundated a portion of the Menomonee River Parkway Drive which lies parallel to and east of the River. Farther upstream, floodwaters inundated that portion of Currie Park Golf Course that lies along the Menomonee River reach bounded by N. Mayfair Road (STH 100) on the east and W. Capitol Drive (STH 190) on the north.

Floodwaters occupied much of the natural floodlands along the Menomonee River in heavily urbanized Milwaukee County. Relatively few flood problems resulted, however, because this riverine land is part of the Milwaukee County park system and serves recreational and aesthetic functions that are compatible with occasional inundation. Figure 51 shows an example of the

Figure 51

FLOODING OF MENOMONEE RIVER PARKWAY LANDS BETWEEN W. NORTH AVENUE AND W. BURLEIGH STREET: SEPTEMBER 18, 1972



In addition to meeting important recreational, aesthetic, and ecological needs of the urban population and environment, long continuous corridors of riverine area park and open space lands like those shown in the photograph are compatible with periodic inundation by floodwaters in that no, or relatively little, damage is incurred. During major flood events, these riverine area park and open space lands perform vital floodwater conveyance and storage functions.

Source: SEWRPC.

September 18, 1972, inundation of park lands along the Menomonee River Parkway Drive at locations between W. North Avenue and W. Burleigh Street.

As noted above, flood problems also developed along Underwood Creek. Secondary flooding occurred in the City of Wauwatosa along Underwood Creek Parkway Drive south of Underwood and just east of the Waukesha-Milwaukee County Line. As shown in Figure 52, portable pumps were needed to relieve the surcharged sanitary sewers. At the Waukesha-Milwaukee County Line, W. Bluemound Road (USH 18) was inundated by up to 18 inches of water and closed to traffic. Farther upstream in the Village of Elm Grove, high stages on Underwood Creek overtopped several bridges that provide access to a motel, apartments, and private residences. In contrast with the 1960 flood, no damage was reported in the business district of Elm Grove. There were, however, scattered instances of basement flooding reported along Legion Drive north of the business district and east of Underwood Creek. W. North Avenue was overtopped by Underwood Creek and closed to traffic. Flooding along Honey Creek probably was confined to the City of West Allis where scattered cases of sewer backup were reported, some of them close to Honey Creek.

Figure 52

PUMPING FROM SURCHARGED SANITARY SEWERS ALONG UNDERWOOD CREEK IN THE CITY OF WAUWATOSA SEPTEMBER 1972

During major floods, overland flow often enters and surcharges sanitary sewers, thereby forcing water into the basements and lower levels of private residences and other structures served by the sewers. This situation, referred to as secondary flooding, is sometimes relieved by use of portable pumps to remove water from the sanitary sewers.

Source: SEWRPC.

The September 18, 1972, flood event occurred as a result of widespread rainfall observed over the Region during the period of Saturday, September 16, through Monday, September 18. Rainfall amounts recorded at the 16 stations existing in the Region at that time, and for which observations were published by the National Weather Service, varied from a low of 1.11 inches at Lake Geneva to a high of 3.56 inches at Waukesha. The causative rainfall event was concentrated in an east-west zone approximately encompassing the northern halves of Milwaukee and Waukesha Counties and, therefore, most of the Menomonee River watershed. Two-day rainfall yields in this zone exceeded 2.5 inches while an average rainfall of 2.74 inches, determined by application of the Thiessen polygon procedure, occurred on the Menomonee River watershed.

A hydrograph for this flood as measured on the Menomonee River at Wauwatosa (USGS Gage No. 04087120) is shown in Figure 50. The direct runoff was determined to be 1.53 inches, which is the seventh largest runoff that occurred during the 12-year period of record from 1962 through 1973. The peak daily flow for the flood occurred on Monday, September 18, when 2,520 cfs were recorded and the instantaneous peak flow, which also occurred on that date, was 6,610 cfs and had a recurrence interval of about nine-years. The September 18, 1972, peak daily discharge of 2,520 cfs on the Menomonee River at Wauwatosa was the third largest ever recorded, only 350 cfs less than the July 18, 1964, peak daily discharge which was the second largest. As shown on Figure 50, the September 18 peak daily flow was followed by a secondary peak daily discharge of 1,960 cfs on September 21, 1972, as a result of scattered rainfall which occurred in the watershed during the three day period following September 18.

The July 18, 1964, and September 18, 1972, summer rainfall floods compared closely in duration of rainfall, instantaneous discharge, peak daily discharge, and direct runoff volume. Although these two floods were very similar with respect to the above factors, the quantity of rainfall associated with and occurring immediately before the peak flow differed markedly. The Menomonee River watershed received an average of 6.16 inches of rain on July 17, and 18, 1964, whereas only 2.74 inches of rain fell on September 17, and 18, 1972. These two markedly different rainfall events produced similar flood events because watershed moisture conditions prior to the July 1964 flood were very dry, whereas high moisture levels existed in the basin before the September 1972 flood.

In June 1964, the total precipitation measured at the three in-watershed weather observation stations ranged from 30 to 50 percent of average. These dry conditions continued into the first half of July, in that the three stations recorded rainfall amounts during that period that were 40 to 90 percent of average. In contrast, the September 18, 1972, flood was preceded by an unusually wet two-and-one-half month period during which rainfall amounts recorded at the three in-watershed stations were about 50 to 70 percent above average. Therefore, although the rainfall prior to the September 18, 1972 flood was only about 45 percent of that preceding the July 18, 1964, flood, the September 1972 precipitation fell on a saturated watershed in contrast with the dry conditions prior to the July 1964 flood—with the result that the ensuing direct runoff volumes and peak flows were similar.

Flood of April 21, 1973

The April 21, 1973, flood event, the most severe recorded to date within the watershed in terms of damage and disruption, resulted from moderate rainfall volumes occurring over the entire watershed under very wet antecedent moisture conditions. Extensive portions of the natural floodlands were inundated throughout much of the watershed with damage and disruption concentrated in those riverine areas that had been converted to urban uses. The spatial extent of the flood damage and disruption as well as the types of flood problems are shown on Map 51. Although the April 21, 1973, event caused flood problems throughout most of the urban area, which at that time encompassed about 54 percent of the watershed, the damage and disruption were most serious along Underwood Creek in the Village of Elm Grove and along the Menomonee River in the City of Wauwatosa.

The immediate cause of the April 21, 1973, flooding in the Menomonee River watershed was widespread rainfall that occurred throughout the Region during the period of April 18 through April 21, with most of the rainfall being concentrated on Friday and Saturday, April 20 and 21. All 16 National Weather Service stations in operation within southeastern Wisconsin at that time recorded rainfall, with the April 20 and 21 totals ranging from a low of 1.15 inches at Union Grove in Racine County to a high of 4.07 inches at Milwaukee North station in Milwaukee County. Regional rainfall amounts for the two days were largest along an east-west zone positioned through the middle of Milwaukee and Waukesha Counties. The zone of maximum rainfall included much of the Menomonee River watershed : 3.05 inches were recorded at the City of West Allis in the lower reaches of the watershed; 3.85 inches were measured at Mount Mary College in the middle portion of the watershed; and 2.33 inches observed at the Village of Germantown in the watershed headwaters. These three in-watershed rainfall totals were among the largest six values recorded throughout the Region and, therefore, as true also in the July 18, 1964, flood, the Menomonee River watershed was one of the areas on which the regional rainfall was concentrated.

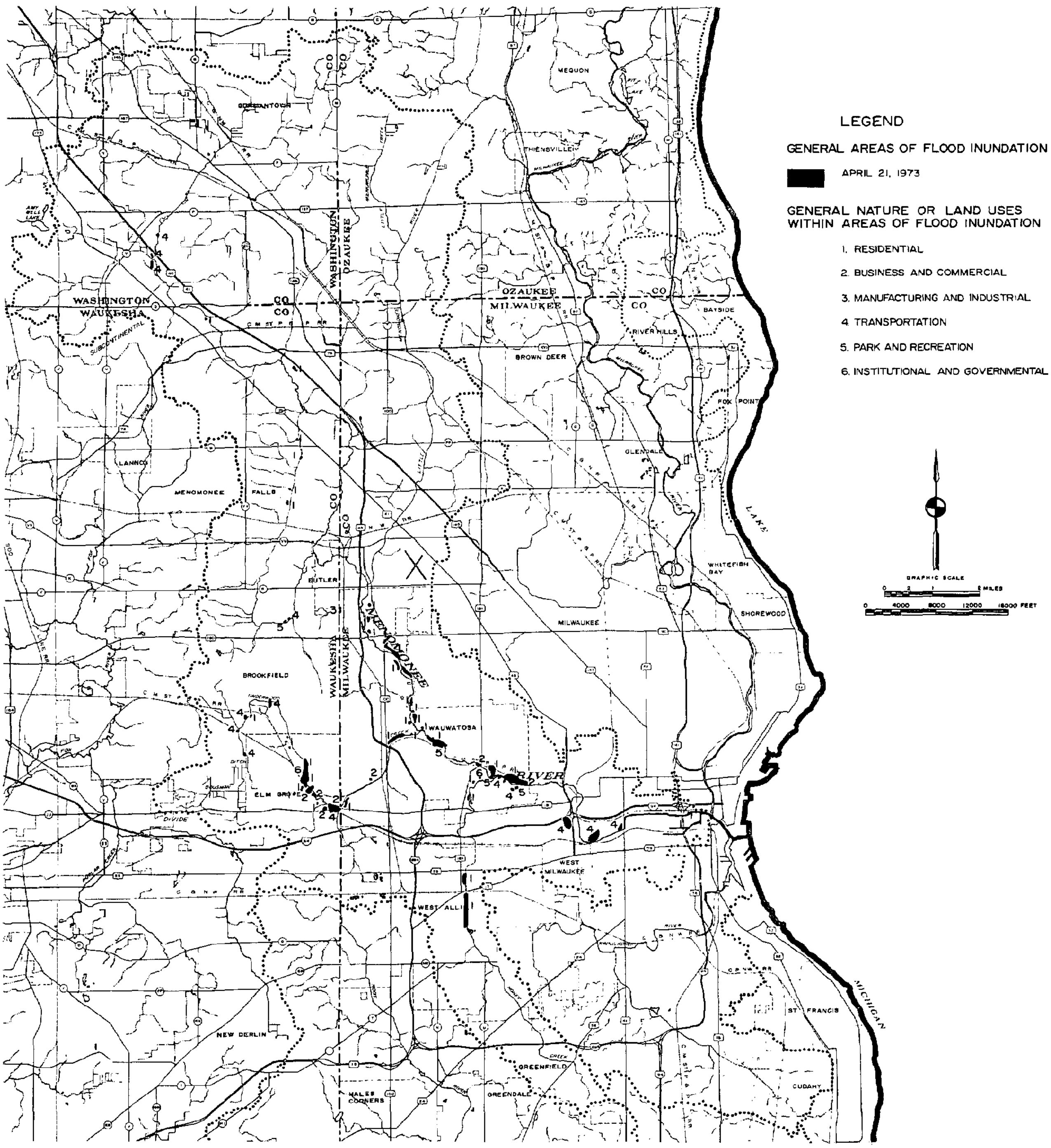
Isohyetal lines constructed from rainfall amounts reported by National Weather Service stations in and near the watershed are shown on Map 52 and illustrate the spatial distribution of the April 20 and 21, 1973, rainfall. Based on a Thiessen polygon analysis, the average rainfall received over the watershed in the two-day period was 3.16 inches. Assuming that approximately 80 percent, or 2.5 inches, of this occurred during a continuous eight-hour period late Friday night and early Saturday morning, as was the case at the Milwaukee National Weather Service station where hourly rainfall amounts are recorded, the recurrence interval of this storm was only about six years.

Although the rainfall was not so severe as that preceding some previous major floods, such as the 6.16 inch two-day watershed average immediately before the July 18, 1964 flood, the resulting direct runoff discharges and volumes were surprisingly large. Figure 50 shows the flood hydrograph as constructed from discharge measurements made at the stream gage on the Menomonee River at Wauwatosa (USGS Gage No. 04087120). The direct runoff from the April 21, 1973, flood was determined to be 3.06 inches which is the largest runoff volume recorded at that location during the period of record that began with water year 1962. As shown in Figure 50, the peak daily flow which occurred on Saturday, April 21, was 6,380 cfs which is the largest ever recorded at that location. The instantaneous peak flow of 13,500 cfs, which also occurred on April 21, was the largest such discharge ever recorded, 104 percent larger than the previous high of 6,610 cfs recorded on September 18, 1972, and with an estimated recurrence interval of about 95 years. An instantaneous peak flow of 360 cfs was recorded on April 21, 1973, at the partial record station on the Little Menomonee River (USGS Gage No. 040870.5). This peak flow was the largest ever observed there, while an instantaneous peak flow of 640 cfs was observed on the same date on Honey Creek (USGS Gage No. 040871) with this discharge being the second largest ever recorded at that site.

The explanation for the apparent inconsistency between causative rainfall and the resulting runoff, with the former being moderate relative to other major flood events and the latter being very large relative to those flood events, again lies in the antecedent moisture conditions. Precipitation totals within the watershed during January, February, and March 1973 were close to average. During the first 19 days of April, this normal precipitation pattern continued at the Germantown observation station while the Mount Mary station recorded precipitation 90 percent above average and West Allis precipitation was 27 percent above average. The large precipitation amounts that occurred in the lower two-thirds of the watershed during the first 19 days of April 1973 were influenced by a heavy snowfall on April 8 through 12, during which 15.7 inches of snow fell at the Milwaukee National Weather Service Station with 11.6 inches occurring on April 9. Although snowfall measurements are not routinely made at the three in-watershed stations, total precipitation amounts recorded at those locations at the time of the Milwaukee snowfall indicated that similar snowfall amounts occurred in the lower two-thirds of the watershed with an insignificant amount occurring in the headwater areas. This snowfall was followed by several days of warm weather so that the snow cover had melted away by about April 15. This was followed by several days of light rain prior to the heavy rainfalls of April 20 and 21, 1973, and the subsequent severe flood.

Map 51

FLOOD PROBLEM AREAS IN THE MENOMONEE RIVER WATERSHED FOR THE APRIL 1973 FLOOD

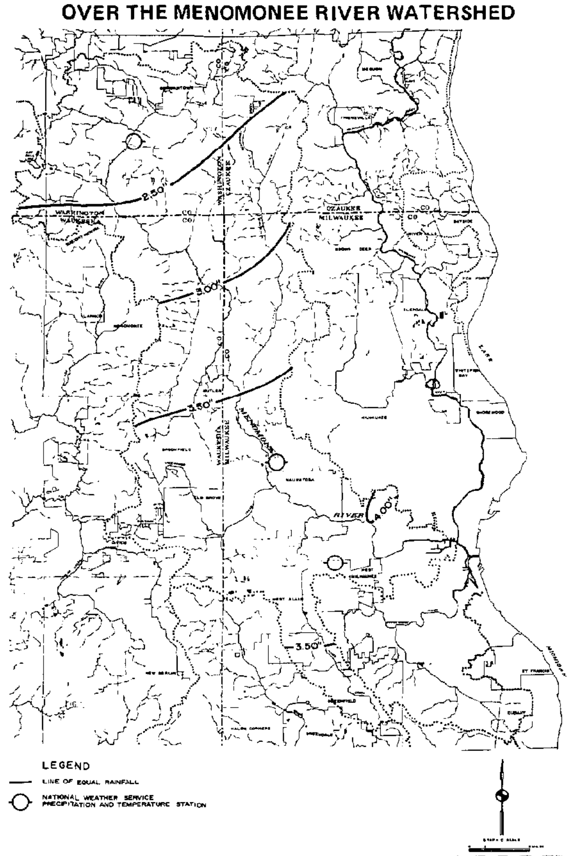


The April 21, 1973, flood event, which was the most severe recorded to date in terms of damage and disruption, resulted from moderate rainfall volumes occurring over the entire watershed under very wet antecedent moisture conditions. The damage and disruption were most serious along Underwood Creek in the Village of Elm Grove and along the Menomonee River in the City of Wauwatosa.

Source: SEWRPC.

Map 52

RAINFALL OF APRIL 20-21, 1973, OVER THE MENOMONEE RIVER WATERSHED



The average rainfall over the watershed which caused the April 1973 flood event was slightly in excess of three inches in a two-day period. Because of high antecedent moisture conditions, this rather moderate rainfall produced very large flood discharges in the watershed. A peak flood discharge of approximately 13,500 cubic feet per second having a recurrence interval of approximately 95 years was recorded on the Menomonee River in the City of Wauwatosa. These large flood flows were accompanied by widespread damage and disruption within the watershed.

Source: SEWRPC.

In summary, then, the severity of the April 21, 1973 flood is attributable to moderate rainfall of 3.16 inches over the watershed which occurred under very wet antecedent moisture conditions in the lower two-thirds of the watershed thereby producing a direct runoff of 3.06 inches which was 97 percent of the rainfall immediately prior to the flood. The wet antecedent conditions were the result of the rapid melting of the heavy snowfall received early in April and the light rain that occurred subsequent to that melting. The April 21, 1973 flood provides another illustration of the extreme sensitivity of rainfall induced floods to antecedent moisture conditions in the Menomonee River watershed.

Village of Elm Grove: Underwood Creek occupied its floodlands along the entire 2.25 mile reach through the Village of Elm Grove during the April 21, 1973, flood, causing extensive damage to commercial, industrial, and residential property and disruption of community activities. The lateral extent of overland flooding is shown on Map 53, and is based on the observations of SEWRPC flood damage survey interviewees and on measured high water elevations.

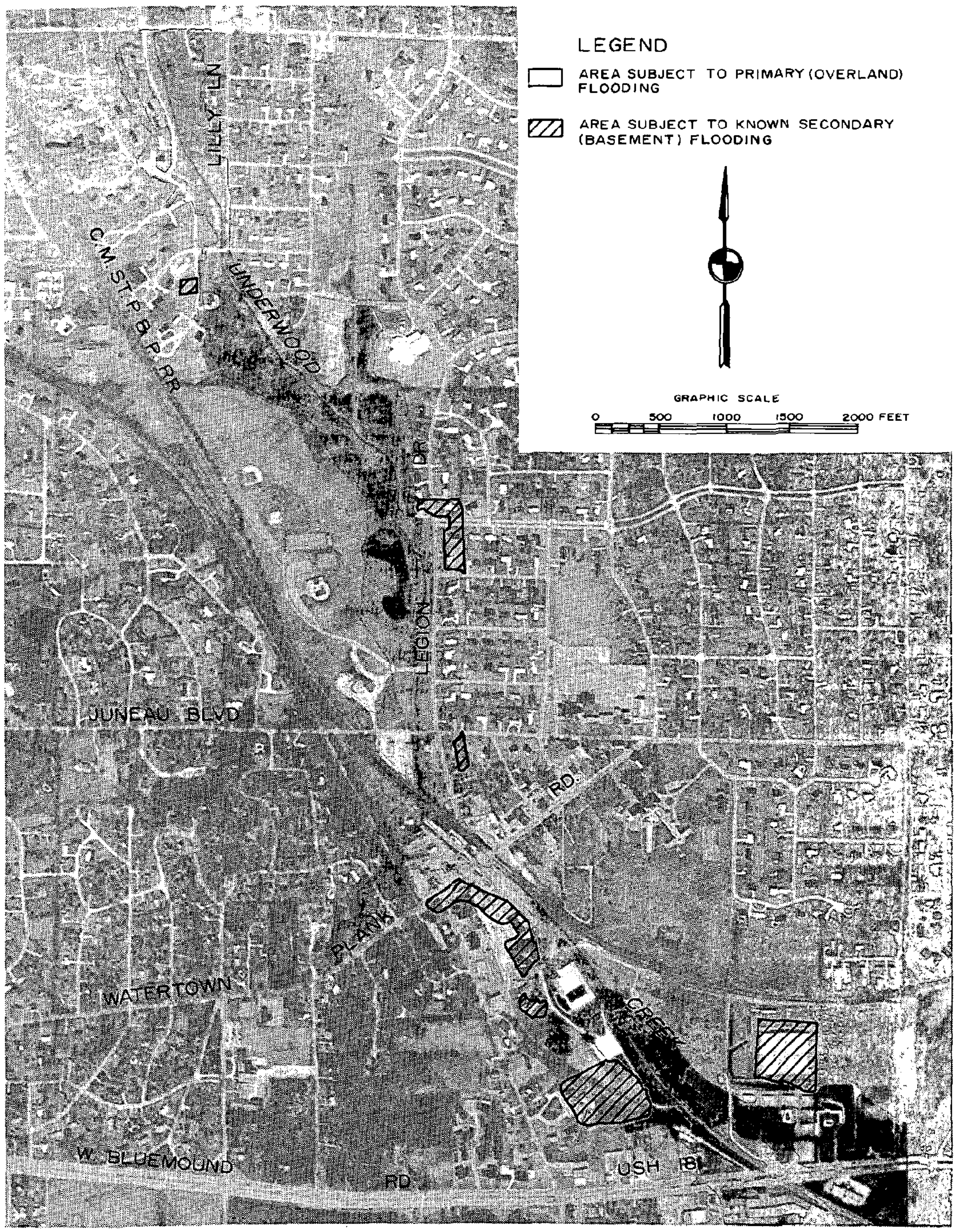
A detailed summary of the field interview findings is presented in Table 34. As indicated, interviews were completed with the owners or occupants of 13 structures located within the area of overland flooding. These structures consisted of three single-family residential structures, nine commercial and industrial structures, and one other private structure. Based on data obtained from the sample, it is estimated that about one-half of the 26 structures in the area of overland flooding have basements and that all of these incurred flooding. In addition, 11 of the 13 structures in the sample reported first floor flooding. Interviews were also completed with the owners or occupants of 52 structures—32 single-family residences, one multi-family residence, 16 business-commercial buildings, and three other structures—in the contiguous secondary flooding area. About 85 percent of these structures have basements and somewhat less than half of those with basements reported secondary flooding.

Beginning at the downstream end of Underwood Creek in the Village of Elm Grove, and as shown on Map 53, an apartment complex, a motel, and private residences located along W. Bluemound Road (USH 18) were damaged with the apartments and the motel experiencing first floor flooding. As has been the case in most major floods, a section of W. Bluemound Road in this area near the Waukesha-Milwaukee County Line was over-topped and closed to traffic. Primarily as a result of the April 1973 flooding, the Village carried out a channel modification program in this area, completing it in late 1973.

Farther upstream, considerable damage occurred in the business area of the Village where there has been an extensive encroachment of buildings and fill into the floodlands. Underwood Creek rose rapidly during the early morning hours of Saturday, April 21, 1973 and, as shown on Map 53, overtopped Watertown Plank Road, and the parking area immediately to the south and also flooded the area immediately upstream. As a result of the extent and depth of inundation in this area, people were observed, as shown in Figure 53, moving about in small boats. The basements and, in some instances, the first floors of many buildings in the business area were inundated. One of several fuel oil tanks located on the Underwood Creek floodplain between Watertown Plank Road and Juneau Boulevard was tipped by the buoyant force of rising floodwaters, spilling 8,000 gallons of oil into the creek. The oil was carried by the floodwaters and added to the difficulty of post-flood clean-up work at downstream structures. An earthen berm around the oil storage tanks prevented their being carried downstream. The floodwaters rose so rapidly that there was insufficient time to move buses parked at a bus company lot adjacent to Underwood Creek at Juneau Boulevard on the north end of the business district. As a result, it was necessary to remove the wheels from the buses in order to clean the silt and sediment from them.

Map 53

OVERLAND FLOODING ALONG UNDERWOOD CREEK IN THE VILLAGE OF ELM GROVE: APRIL 21, 1973



The April 1973 flood caused severe damage and disruption to low-lying lands along Underwood Creek in the Village of Elm Grove. It is estimated that the Village sustained in excess of 1.5 million dollars in flood damages with these damages being concentrated in the commercial areas located along Underwood Creek in the vicinity of the Watertown Plank Road.

Source: SEWRPC.

Table 34

RESULTS OF INTERVIEWS CONDUCTED IN THE VILLAGE OF ELM GROVE CONCERNING THE APRIL 21, 1973 FLOOD

Universe and Sample Parameters			Overland Flooding Area	Secondary Flooding Area	Combined Area
Universe	Total Number of Major Structures (1973)		26.0	--[a]	--[a]
Sample Size	Number		13.0	52.0	65.0
	Percent of Total Number of Structures		50.0	--[a]	--[a]
Structure Types Based on Sample	Single-Family Residence	Number	3.0	32.0	35.0
		Percent of Sample	23.1	61.5	53.8
	Multi-Family Residence	Number	0.0	1.0	1.0
		Percent of Sample	0.0	1.9	1.5
	Business-Commercial	Number	9.0	16.0	25.0
		Percent of Sample	69.2	30.8	38.5
	School	Number	0.0	1.0	1.0
		Percent of Sample	0.0	1.9	1.5
	Other Public	Number	0.0	2.0	2.0
		Percent of Sample	0.0	3.9	3.1
	Other Private	Number	1.0	0.0	1.0
		Percent of Sample	7.7	0.0	1.5
Basement Information Based on Sample	Number with basements		6.0	44.0	50.0
	Percent of Sample		46.2	84.6	75.6
Basement Flooding Information Based on Sample.	Attributed to Sewer Back-Up	Number	0.0	4.0	4.0
		Percent of Sample	0.0	7.7	6.2
	Attributed to Overland Flooding	Number	3.0	3.0	6.0
		Percent of Sample	23.1	5.8	9.2
	Attributed to a Combination of Above, Others, or Unknown	Number	3.0	12.0	15.0
		Percent of Sample	23.1	23.1	23.1
	Total Basement Flooding	Number	6.0	19.0	25.0
		Percent of Sample	46.2	36.5	38.5
First Floor Flooding Information Based on Sample.	Number		11.0	0.0	11.0
	Percent of Sample		84.6	0.0	10.8

[a]*Not available.*
Source: SEWRPC.

Flood damage and disruption north of the business district were confined to residential areas. As shown on Map 53, many local streets were inundated including short sections of Juneau Boulevard and Marcella Street, both of which cross Underwood Creek, a five-block-long portion of Legion Drive which parallels and lies east of the Creek, and short segments of Underwood Parkway and Mount Kisco Drive which lie west of and generally parallel to Underwood Creek. In addition to the traffic disruption and overland flood damage, many residences incurred basement flooding. A relatively large portion of Village park and open space land along both sides of Underwood Creek was inundated but no serious damage occurred.

Inundation problems were also reported along the easterly flowing Underwood Creek tributary that lies north of and approximately parallel to Watertown Plank Road. Inasmuch as high water levels along this tributary are largely independent of flood stages on Underwood Creek, the tributary was not included in the flood survey since it is defined in the context of the watershed planning program as a local drainage channel with stormwater problems, as opposed to a river reach with flood problems.

City of Wauwatosa: A 7.14 mile long reach of the Menomonee River, a 2.57 mile long segment of Underwood Creek, and a 1.21 mile reach of Honey Creek are contained within the City of Wauwatosa. Flood damage and disruption were incurred at scattered locations along each of these three stream reaches during the April 21, 1973 flood. The lateral extent of overland flooding is shown on Map 54. Overland flood areas delineated on the map are based on both the observations of interviewees and on measured high water elevations.

A detailed summary of the findings of sample field interviews conducted by the Commission staff is presented in Table 35. Interviews were completed with the owners or occupants of 18 structures located within the area of overland flooding. These buildings consisted of three residential structures, five business-commercial structures, and 10 manufacturing-industiral structures. Data derived from this sample indicate that about 45 percent of the structures in the area of overland flooding have basements and that almost all of these incurred basement flooding. Interviews also were completed with the owners or occupants of 129 structures in the contiguous secondary flooding area: 104 single-family residences, seven two-family residences, one multi-family residence, eight business-commercial buildings, two manufacturing-industrial buildings, three schools, a church, and three other buildings. About 90 percent of these structures have basements and over 70 percent of those with basements reported secondary flooding. Secondary flooding was reported along the Menomonee River, Underwood Creek, and Honey Creek within the City of Wauwatosa.

One of the most serious examples of flooding in Wauwatosa occurred on the north side of the Menomonee River reach bounded by Hawley Road on the downstream end and about 66th Street extended on the upstream end. As a result of the overland flooding experienced in this area (see Map 54), many commercial and industrial buildings were damaged. Overland flooding also occurred on the opposite side of the river but caused little damage relative to that experienced on the north side of the river because the area to the south is part of the Milwaukee County Park System and therefore is not susceptible to significant flood damage.

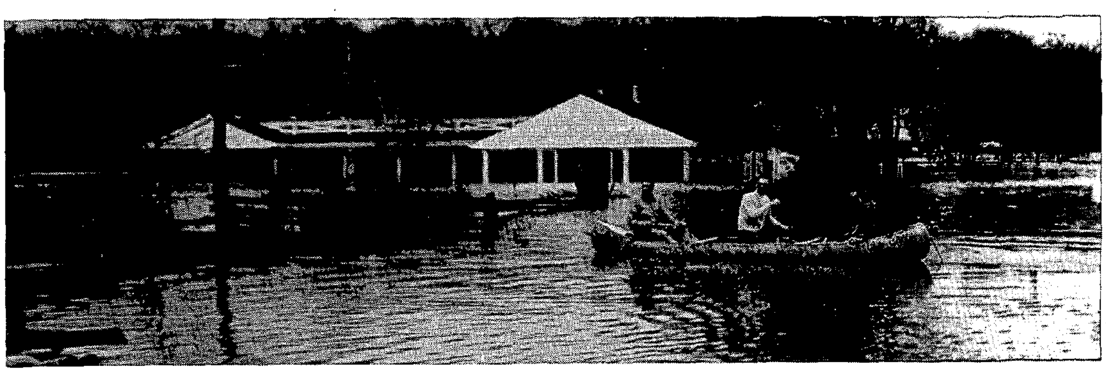
The next upstream concentration of flood damage and disruption occurred on the north side of the Menomonee River reach extending from the 68th Street bridge upstream through Wauwatosa's Hart Park. Police and firemen evacuated about 22 families from this area. Boats were used, and in some cases the rescuers tied ropes between trees and other objects to serve as hand lines, providing protection against the force of the flowing floodwaters. Both the 68th and 70th Street bridges were closed to traffic as a result of flood waters that overtopped the bridges or their approach roads. As shown on Map 54, overland flooding occurred in the residential area between and upstream of the two bridges with the peak flood stage exceeding the first floor elevations of some of the houses. Floodwaters covered portions of the track, football field, tennis courts, and parking lot in Hart Park and also entered the park maintenance building.

Instances of flood damage and disruption were reported along the Menomonee River in Wauwatosa upstream of Hart Park. Examples of reported damage include inundation of the Menomonee River Parkway Drive near Hoyt Park and also at a point several blocks upstream of North Avenue and near Mount Mary College and scattered basement flooding attributed to sewer backup.

The Milwaukee County Park Commission reported a loss of about $2,400 as a result of flooding of the pool filter room, the boiler room, and a storage area at Hoyt Park. Eleven picnic tables with a total value of $300 were floated from the Hoyt Park area and not recovered. As a result of closure of the Hansen Golf Course, which is also part of the Milwaukee County Park System, about $1,000 in revenue was lost while a $1,250 loss was incurred at the Currie Park Golf Course when an electric pump motor, two transformers, and associated controls

Figure 53

FLOODING IN THE VILLAGE OF ELM GROVE: APRIL 1973



This photograph, which shows the area immediately east of Underwood Creek near the intersection of Juneau Boulevard and Legion Drive in Elm Grove, illustrates the depth and extent of the overland flood that was experienced throughout much of the Village.

Source: Village of Elm Grove.

Table 35

RESULTS OF INTERVIEWS CONDUCTED IN THE CITY OF WAUWATOSA CONCERNING THE APRIL 21, 1973 FLOOD

Universe and Sample Parameters			Overland Flooding Area	Secondary Flooding Area	Combined Area
Universe	Total Number of Major Structures (1973)		74.0	--[a]	--[a]
Sample Size	Number		18.0	129.0	147
	Percent of Total Number of Structures		24.0	--[a]	--[a]
Structure Types Based on Sample	Single-Family Residence	Number	3.0	104.0	107
		Percent of Sample	16.7	80.0	72
	Two-Family Residence	Number	0.0	7.0	7
		Percent of Sample	0.0	5.0	5
	Multi-Family Residence	Number	0.0	1.0	1
		Percent of Sample	0.0	1.0	1
	Business-Commercial	Number	5.0	8.0	13
		Percent of Sample	27.8	6.0	9
	Manufacturing-Industrial	Number	10.0	2.0	12
		Percent of Sample	55.5	2.0	8
	School	Number	0.0	3.0	3
		Percent of Sample	0.0	2.0	2
	Church	Number	0.0	1.0	1
		Percent of Sample	0.0	1.0	1
	Other Public	Number	0.0	2.0	2
		Percent of Sample	0.0	2.0	1
	Other Private	Number	0.0	1.0	1
		Percent of Sample	0.0	1.0	1
Basement Information Based on Sample	Number with Basements		8.0	125.0	133
	Percent of Sample		44.4	96.2	90
Basement Flooding Information Based on Sample.	Attributed to Sewer Back-Up	Number	0.0	65.0	65
		Percent of Sample	0.0	50.0	44
	Attributed to Overland Flooding	Number	7.0	3.0	10
		Percent of Sample	38.9	2.3	7
	Attributed to a Combination of Above Others, or Unknown	Number	0.0	20.0	20
		Percent of Sample	0.0	15.4	13
	Total Basement Flooding	Number	7.0	88.0	95
		Percent of Sample	38.9	67.7	64
First Floor Flooding Information Based on Sample.	Number		13.0	0.0	13
	Percent of Sample		72.2	0.0	9

[a] *Not available.*

Source: SEWRPC.

Map 54

OVERLAND FLOODING ALONG THE MENOMONEE RIVER, UNDERWOOD CREEK, AND HONEY CREEK IN THE CITY OF WAUWATOSA: APRIL 21, 1973

HONEY CREEK AND MENOMONEE RIVER FROM EAST CITY LIMITS TO HARWOOD AVENUE

LEGEND

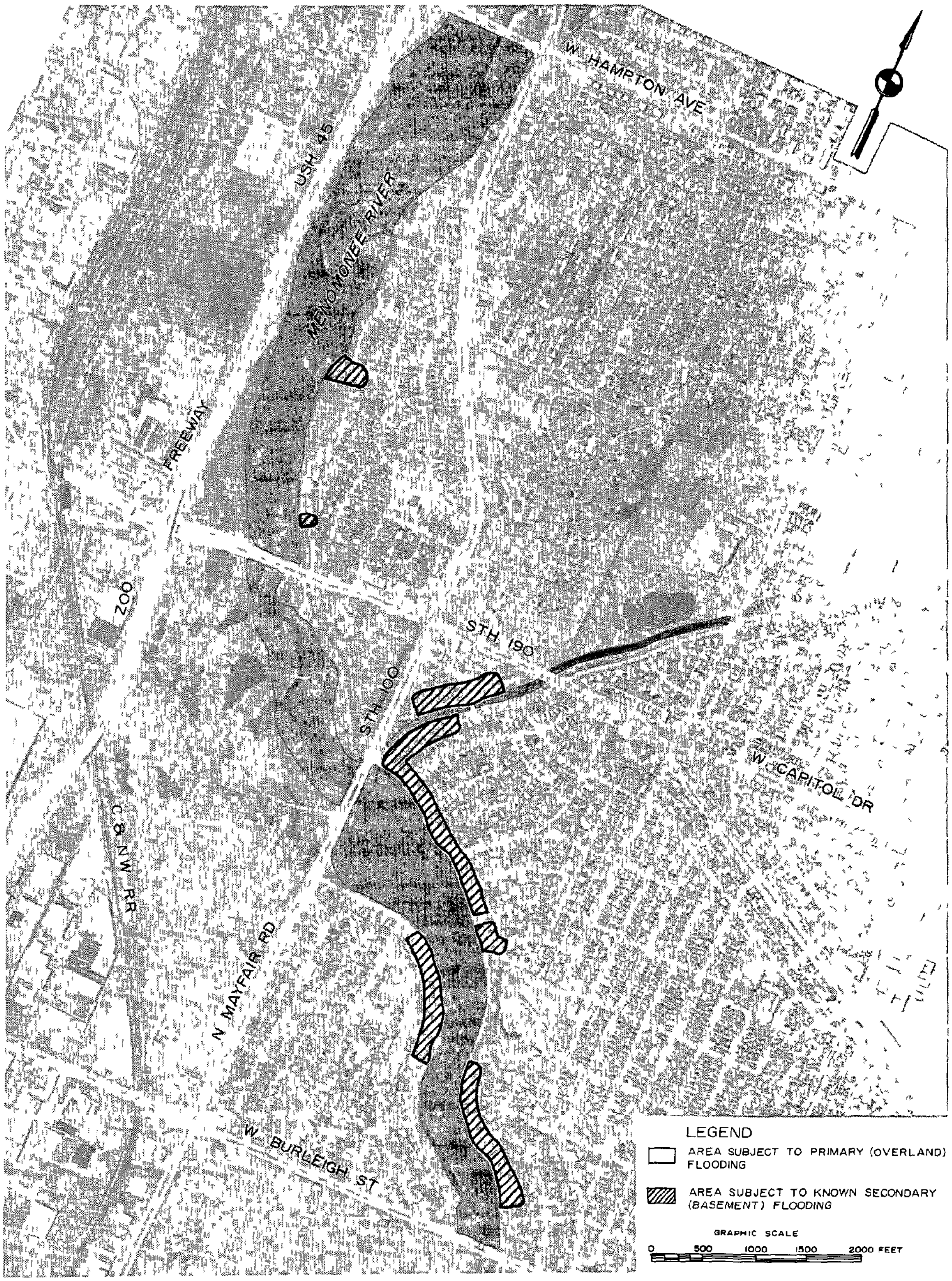
AREA SUBJECT TO PRIMARY (OVERLAND) FLOODING

Map 54 (continued)

MENOMONEE RIVER FROM HARWOOD AVENUE TO W. BURLEIGH STREET

Map 54 (continued)

MENOMONEE RIVER FROM W. BURLEIGH STREET TO W. HAMPTON AVENUE



UNDERWOOD CREEK

LEGEND

AREA SUBJECT TO PRIMARY (OVERLAND) FLOODING

AREA SUBJECT TO KNOWN SECONDARY (BASEMENT) FLOODING

GRAPHIC SCALE

0 500 1000 1500 2000 FEET

The April 21, 1973, flood was the most severe flood event ever experienced by the City of Wauwatosa. Although flooding was experienced along Honey Creek, Underwood Creek, and the Menomonee River, the most serious flood damages occurred in the residential and commercial area lying along the north side of the Menomonee River between Hart Park and the eastern limits of the City. As described in Chapter IV, Volume 2, of this report, various structural and non-structural measures were prepared and evaluated to help resolve the existing flood problem along the three streams in the City of Wauwatosa.

Source: SEWRPC.

were inundated. As a result of excessive moisture conditions, two fairways were closed at Currie Park for almost five weeks.

Although park activities were disrupted and monetary damages incurred, the gravity of the disruption and the magnitude of the monetary damages are certainly less than what would have been experienced had these natural floodplain areas been used for residential, commercial, or industrial development.

Along Underwood Creek, secondary flooding was experienced on the north side of the Creek immediately downstream of the Zoo Freeway (USH 45) and along Underwood Creek Parkway Drive near the Waukesha-Milwaukee County line. The latter area is adjacent to the reach of Underwood Creek that was undergoing a major channelization project at the time of the April 21, 1973 flood. The Milwaukee County Park Commission estimated that a $4,000 loss was incurred as a result of erosion damage at a drop structure along Underwood Creek downstream of the Zoo Freeway (USH 45). As shown on Map 53, overland flooding occurred along Honey Creek downstream of W. Bluemound Road (USH 18) and although the overland flooding was largely confined to the parkway, some basement flooding caused by sewer backup did occur.

Village of Menomonee Falls: The Menomonee River inundated its natural floodplains along much of the 6.77-mile-long reach of the River lying within the Village of Menomonee Falls. Scattered incidence of floodplain inundation also occurred along the 3.29-mile-long segment of Lilly Creek and the 1.35-mile-long portion of Nor-X-Way Channel within the Village. Considering the relatively large amount of stream channel within the Village—the total length of the Menomonee River, Lilly Creek, and Nor-X-Way Channel is 11.41 miles—and considering the extensive occurrence of floodplain inundation, relatively few flood problems occurred in the Village primarily because much of the natural floodlands has been retained in public or private open space.

The lateral extent of overland flooding in the Village of Menomonee Falls is shown on Map 55. The extent of overland flooding shown on this map is based on information provided by flood damage survey interviewees and on recorded high water elevations.

Table 36 presents a detailed summary of the field interview findings. As indicated, interviews were completed with the owners or occupants of five structures, all single-family residential, located within the area of overland flooding and with owners or occupants of 187 structures—159 single-family residences, nine multi-family residences, 18 business-commercial, and one school—in the area having the potential for secondary flooding. Basement flooding was reported for four of the structures in the overland flooding areas and for 69 of the structures in the contiguous secondary flooding area. It is estimated that about 75 percent of the structures in the secondary flooding area have basements.

As shown on Map 55, extensive overland flooding occurred along the 3.06-mile-long reach of the Menomonee River extending from the east limits of the Village at the Waukesha-Milwaukee County Line upstream to Pilgrim Road (CTH YY). This entire floodland area is in open space uses with much of it being under Village ownership and serving as a parkway while the remainder consists of portions of a private golf course and other private lands. Essentially no secondary flooding was found to occur along this reach of the Menomonee River, except for an area immediately northeast of the intersection of Fond du Lac Avenue and Lilly Road where several instances of basement flooding were reported. Although this inundation occurred near the floodlands, it appeared to be a stormwater problem due in part to an inadequate culvert capacity beneath Fond du Lac Avenue.

The 1.33 mile reach of the Menomonee River extending from Pilgrim Road (CTH YY) upstream through the original Village area to Roger Avenue extended, experienced very little overland flooding primarily because of the steep and incised nature of the channel. No major structures were affected by overland flooding in this reach and, based on the sample interviews, only scattered instances of secondary flooding occurred. Extensive overland flooding occurred in the remaining portion of the Menomonee River in the Village, including overtopping of the private bridge over the river leading to the River Court Shopping Center and inundation of a one-block section of Grand Avenue on the west side of the River. Floodlands in this area are in open space uses and, as a result, no major structures were affected by overland flooding although a few scattered instances of secondary flooding did occur.

Lilly Creek flood problems (see Map 55) were largely confined to the 1.34-mile-long reach between the Menomonee River and Oakwood Drive extended. This area incurred secondary flooding of basements directly attributable to high water levels on Lilly Creek. Although some overland flooding occurred, there were no flood problems reported for the 1.35-mile-long reach of Nor-X-Way Channel located within the Village.

City of Brookfield: Much of the 2.65-mile segment of Underwood Creek lying within the City of Brookfield overflowed its banks on April 21, 1973. Similar floodplain inundation occurred along all of the 2.38-mile-long reach of Butler Ditch in Brookfield and scattered examples of floodplain inundation were reported along a 2.56-mile-long portion of Dousman Ditch within Brookfield. Relatively few structures incurred damages as a result of the flooding but, had the flood stages along the three streams been one to two feet higher, the topography is such that a large number of private residences would have been affected.

The lateral extent of overland flooding is shown on Map 56. The extent of overland flooding shown on this map is based on information provided by flood damage survey interviewees and on recorded high water elevations.

Table 37 presents a detailed summary of the field interview findings. Interviews were completed with the owners or occupants of 49 structures—all single-family residences. All but one of the structures were located outside of but near the area of overland flooding. Although 98 percent of the 49 structures included in the field survey had basements, flooding of basements was reported for only six structures and there was no first floor flooding.

Table 36

RESULTS OF INTERVIEWS CONDUCTED IN THE VILLAGE OF MENOMONEE FALLS ON THE APRIL 21, 1973 FLOOD

Universe and Sample Parameters			Overland Flooding Area	Secondary Flooding Area	Combined Area
Universe	Total Number of Major Structures (1973)		5.0	--[a]	--[a]
Sample Size	Number		5.0	187.0	192.0
	Percent of Total Number of Structures		100.0	--[a]	--[a]
Structure Types Based on Sample	Single-Family Residence	Number	5.0	159.0	164.0
		Percent of Sample	100.0	85.0	85.0
	Multi-Family Residence	Number	0.0	9.0	9.0
		Percent of Sample	0.0	5.0	5.0
	Business-Commercial	Number	0.0	18.0	18.0
		Percent of Sample	0.0	10.0	9.0
	School	Number	0.0	1.0	1.0
		Percent of Sample	0.0	0.5	0.5
	Other Public	Number	0.0	0.0	0.0
		Percent of Sample	0.0	0.0	0.0
	Other Private	Number	0.0	0.0	0.0
		Percent of Sample	0.0	0.0	0.0
Basement Information Based on Sample	Number with Basements		4.0	143.0	147.0
	Percent of Sample		80.0	76.0	77.0
Basement Flooding Information Based on Sample.	Attributed to Sewer Back-Up	Number	0.0	38.0	38.0
		Percent of Sample	0.0	20.0	20.0
	Attributed to Overland Flooding	Number	0.0	3.0	3.0
		Percent of Sample	0.0	2.0	2.0
	Attributed to a Combination of Above, Others, or Unknown	Number	4.0	28.0	32.0
		Percent of Sample	80.0	15.0	17.0
	Total Basement Flooding	Number	4.0	69.0	73.0
		Percent of Sample	80.0	37.0	38.0
First Floor Flooding Information Based on Sample.	Number		0.0	1.0	1.0
	Percent of Sample		0.0	0.5	0.5

[a]*Not available.*

Source: SEWRPC.

As shown on Map 56, overland flooding occurred along the 1.9-mile-long reach of Underwood Creek extending from W. North Avenue (CTH M) upstream to Pilgrim Road (CTH YY). Clearwater Drive, which is located about halfway up this reach, was overtopped and basement and yard flooding was reported in the immediate area. Several bridges farther upstream were overtopped, including Woodbridge Road and Indian Creek Parkway; although yard inundation was reported in this area, only a few incidents of basement flooding occurred.

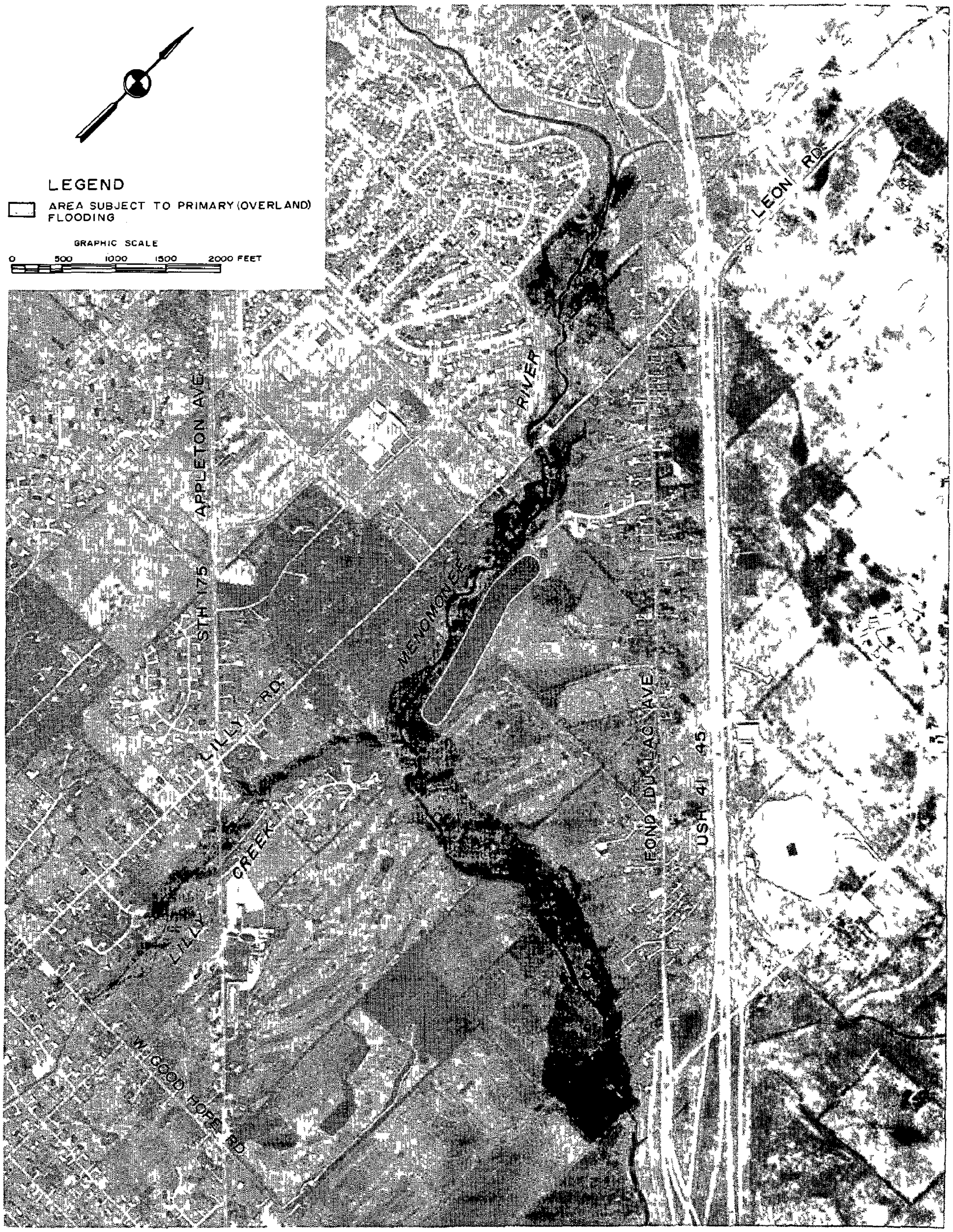
Dousman Ditch overtopped Pilgrim Parkway at several locations, as shown on Map 56, and a few incidents of basement flooding occurred. Map 56 indicates that extensive overland flooding occurred along Butler Ditch and that Lilly Road was over-topped. There were no incidents of structure damage reported for this area primarily because of the open space uses of the floodlands which include a City of Brookfield park along Butler Ditch to the west of Lilly Road.

The W. A. Krueger Company, which is located in Brookfield on the south side of W. Bluemound Road (USH 18) near the Waukesha-Milwaukee County Line, incurred damage as a result of the April 21, 1973 flood. First floor

Map 55

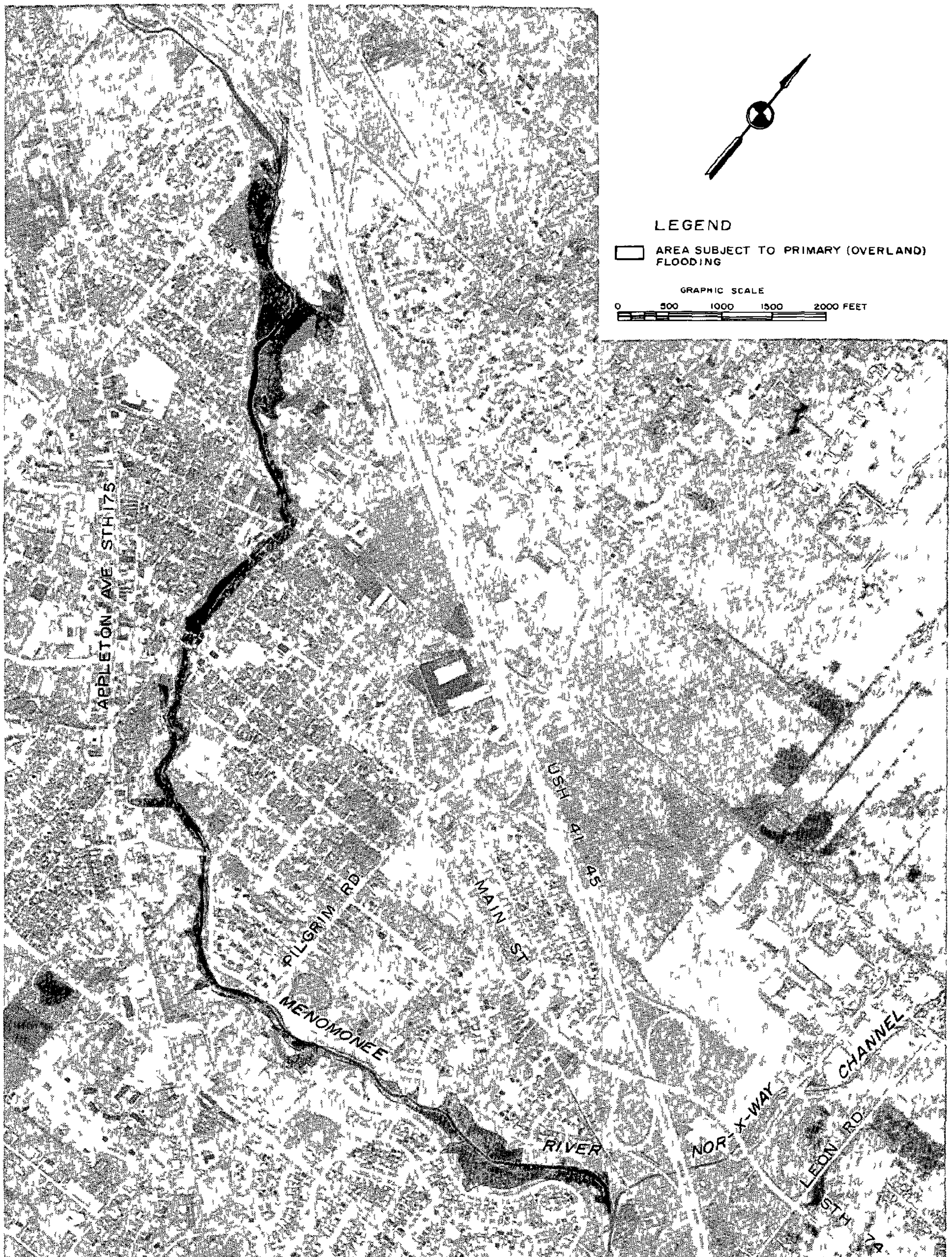
OVERLAND FLOODING ALONG THE MENOMONEE RIVER, LILLY CREEK, AND NOR-X-WAY CHANNEL IN THE VILLAGE OF MENOMONEE FALLS: APRIL 21, 1973

MENOMONEE RIVER FROM EAST VILLAGE LIMITS TO CONFLUENCE WITH NOR-X-WAY CHANNEL AND LILLY CREEK FROM CONFLUENCE WITH MENOMONEE RIVER TO W. GOOD HOPE ROAD



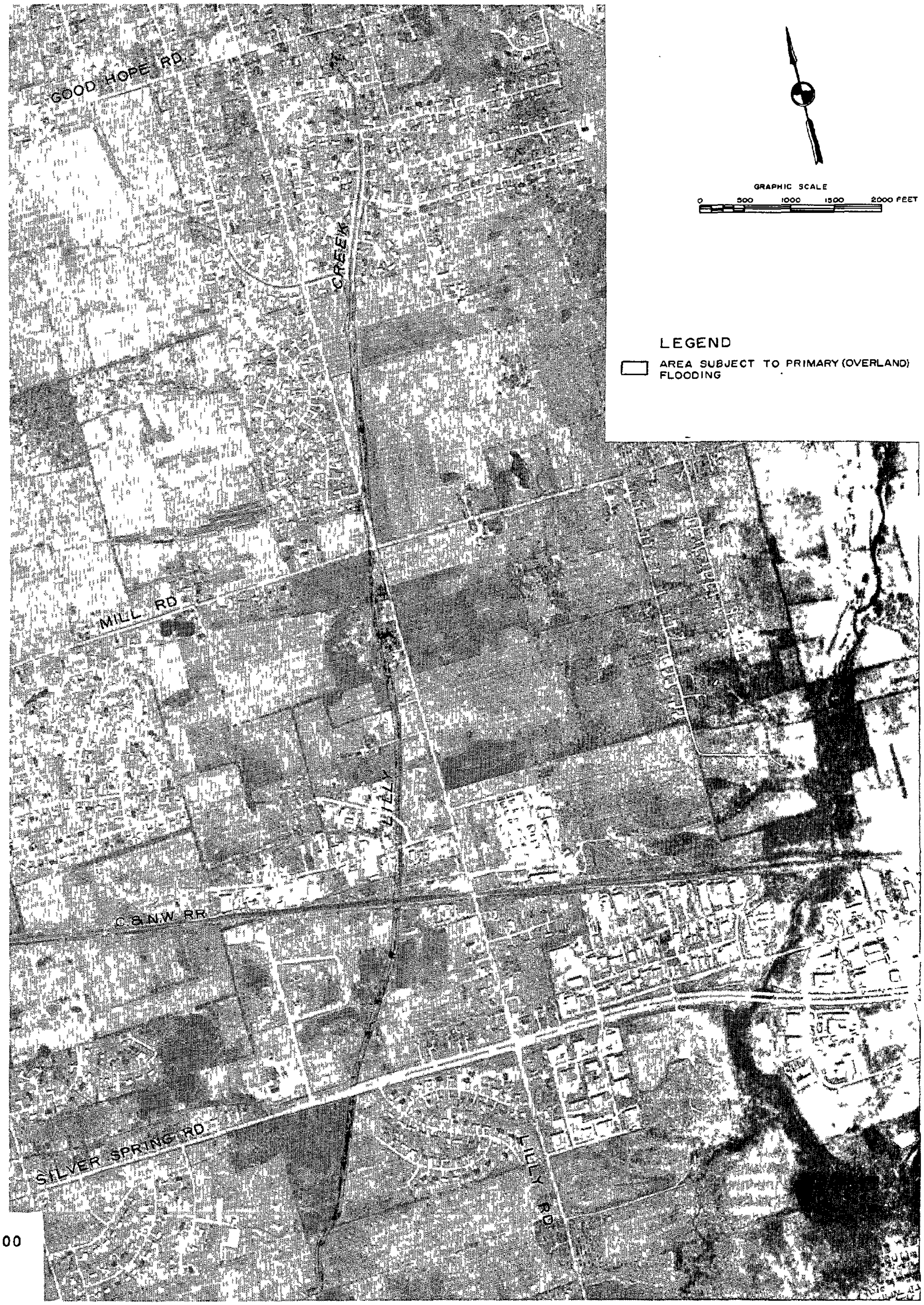
Map 55 (continued)

MENOMONEE RIVER FROM CONFLUENCE WITH NOR-X-WAY CHANNEL TO NORTH VILLAGE LIMITS



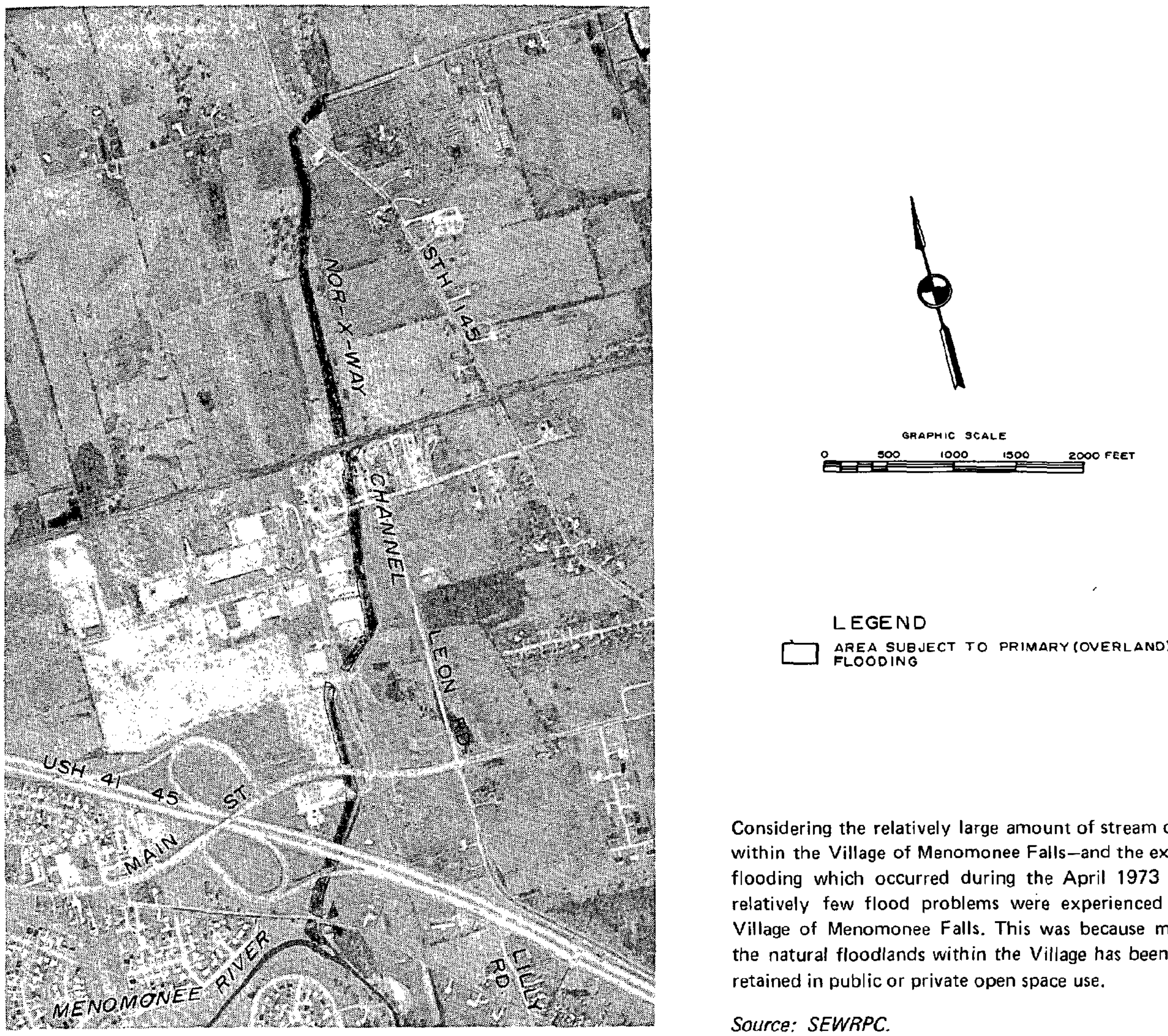
Map 55 (continued)

LILLY CREEK SOUTH FROM W. GOOD HOPE ROAD



Map 55 (continued)

NOR-X-WAY CHANNEL



Considering the relatively large amount of stream channel within the Village of Menomonee Falls—and the extensive flooding which occurred during the April 1973 flood—relatively few flood problems were experienced in the Village of Menomonee Falls. This was because much of the natural floodlands within the Village has been wisely retained in public or private open space use.

Source: SEWRPC.

flooding occurred in the northernmost building and this was attributable primarily to southerly flow across W. Bluemound Road from Underwood Creek.

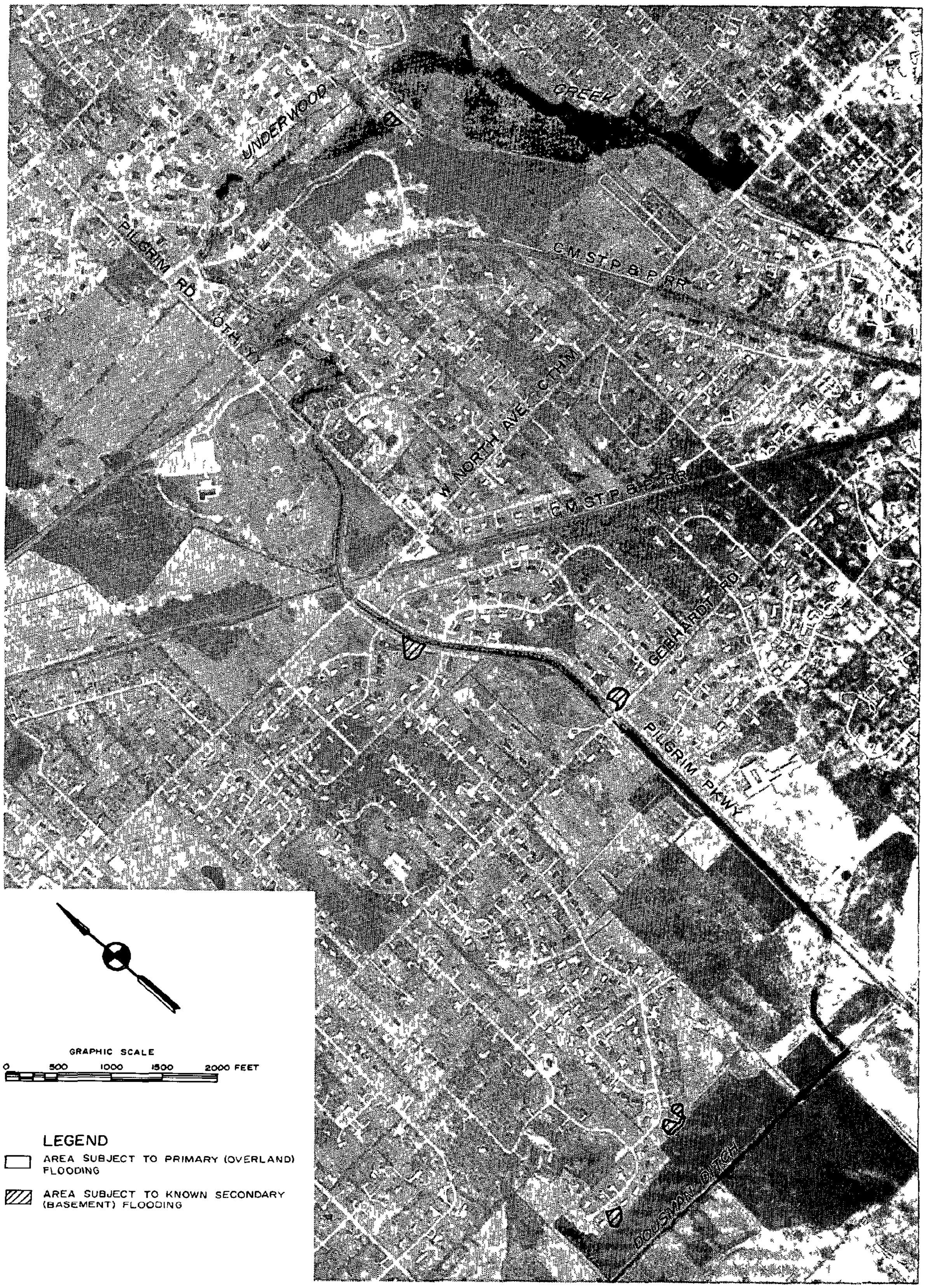
City of Mequon: The Little Menomonee River occupied its floodlands in the City of Mequon along the 3.28-mile reach extending from County Line Road (CTH Q) upstream to Freistadt Road (CTH F). The width of the inundated area was very large—almost one-half mile in some areas—relative to the width of the channel and to the width of floodlands on larger streams in the watershed, thus reflecting the unusual amount of flat, low-lying land that parallels this stream. Floodplain inundation also occurred along the 2.25-mile-long reach of Little Menomonee Creek extending from the Little Menomonee River upstream to Freistadt Road (CTH F). On the Creek the lateral extent of overland flooding was very small relative to that which occurred along the Little Menomonee River. Map 57 shows the overland flooding along the Little Menomonee River and Little Menomonee Creek in the City of Mequon. The delineation of the lateral extent of overland flooding shown on this map is based on the observations of flood damage survey interviewees and on recorded high water elevations.

A detailed summary of the field interview findings is presented in Table 38. No major structures were located within the area of overland flooding. As indicated, interviews were completed with the owners or occupants of 17 structures, including 15 single-family residences, located adjacent to the overland flooding area. About three-fourths of these structures had basements, but

Map 56

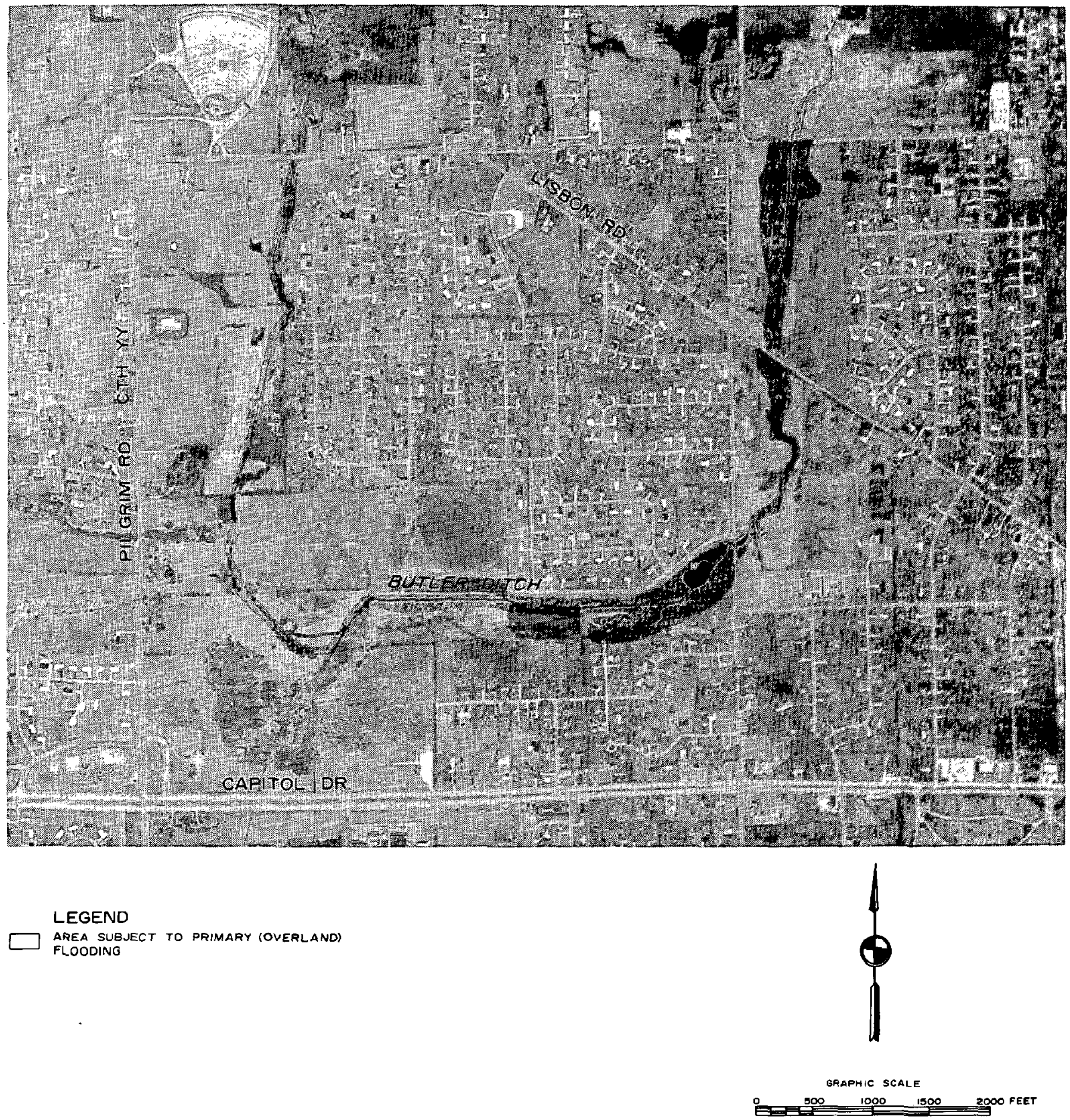
OVERLAND FLOODING ALONG UNDERWOOD CREEK, DOUSMAN DITCH, AND BUTLER DITCH IN THE CITY OF BROOKFIELD: APRIL 21, 1973

DOUSMAN DITCH AND UNDERWOOD CREEK



Map 56 (continued)

BUTLER DITCH



While the City of Brookfield experienced flooding along the Butler Ditch, the Dousman Ditch, and Underwood Creek during the April 1973 flood, the most serious flood problems in the City occurred along Underwood Creek between Pilgrim Road and Clearwater Drive. The structures along Clearwater Drive are particularly susceptible to damage during major floods inasmuch as they are located on the natural floodplain of Underwood Creek.

Source: SEWRPC.

Table 37

RESULTS OF INTERVIEWS CONDUCTED IN THE CITY OF BROOKFIELD CONCERNING THE APRIL 21, 1973 FLOOD

Universe and Sample Parameters			Overland Flooding Area	Secondary Flooding Area	Combined Area
Universe	Total Number of Major Structures (1973)		1	--[a]	--[a]
Sample Size	Number		1	48.0	49
	Percent of Total Number of Structures		100	--[a]	--[a]
Structure Types Based on Sample	Single-Family Residence	Number	1	48.0	49
		Percent of Sample	100	100.0	100
	Multi-Family Residence	Number	0	0.0	0
		Percent of Sample	0	0.0	0
	Business-Commercial	Number	0	0.0	0
		Percent of Sample	0	0.0	0
	School	Number	0	0.0	0
		Percent of Sample	0	0.0	0
	Other Public	Number	0	0.0	0
		Percent of Sample	0	0.0	0
	Other Private	Number	0	0.0	0
		Percent of Sample	0	0.0	0
Basement Information Based on Sample	Number with Basements		1	47.0	48
	Percent of Sample		100	98.0	98
Basement Flooding Information Based on Sample.	Attributed to Sewer Back-Up	Number	0	0.0	0
		Percent of Sample	0	0.0	0
	Attributed to Overland Flooding	Number	1	0.0	1
		Percent of Sample	100	0.0	2
	Attributed to a Combination of Above, Others, or Unknown	Number	0	5.0	5
		Percent of Sample	0	10.4	10
	Total Basement Flooding	Number	1	5.0	6
		Percent of Sample	100	10.4	12
First Floor Flooding Information Based on Sample.	Number		0	0.0	0
	Percent of Sample		0	0.0	0

[a]*Not available.*

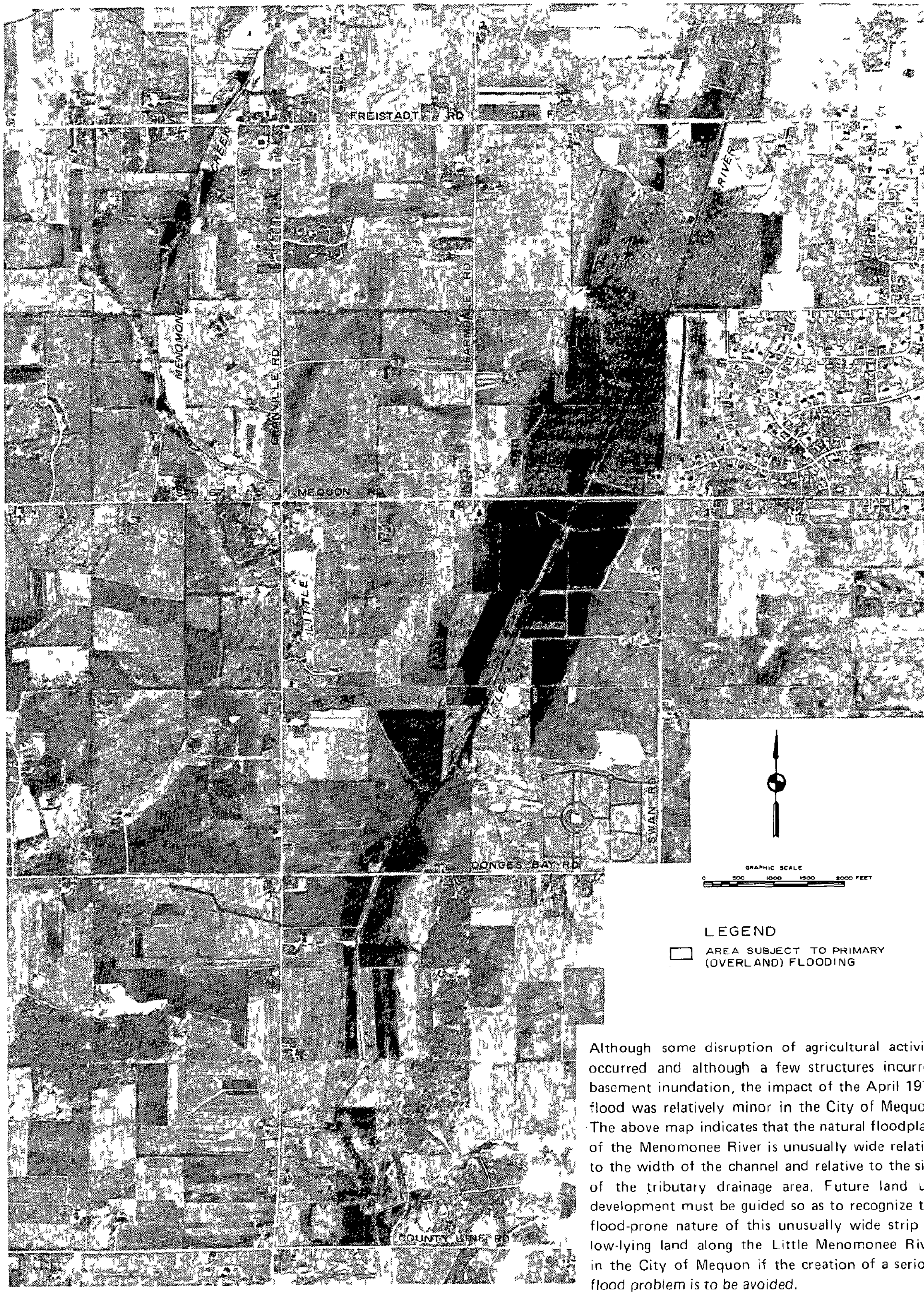
Source: SEWRPC.

basement flooding was reported for only 12 percent of the structures included in the sample. There were no reported cases of first floor flooding.

As shown on Map 57, there are two concentrations of urban development along the Little Menomonee River, each of which is located on the edge of the floodlands. One of these areas is the subdivision on the north side of County Line Road (CTH Q) immediately east of the river and the other is a subdivision north of Mequon Road (STH 167) also east of the river. The low-lying western portion of the latter subdivision experienced street flooding, yard inundation, and some basement damage. There were no flood problems reported within the subdivision to the south although the Little Menomonee River did overtop a 1,200-foot-long portion of County Line Road immediately west of the development.

Map 57

OVERLAND FLOODING ALONG THE LITTLE MENOMONEE RIVER AND THE LITTLE MENOMONEE CREEK IN THE CITY OF MEQUON: APRIL 21, 1973



Although some disruption of agricultural activity occurred and although a few structures incurred basement inundation, the impact of the April 1973 flood was relatively minor in the City of Mequon. The above map indicates that the natural floodplain of the Menomonee River is unusually wide relative to the width of the channel and relative to the size of the tributary drainage area. Future land use development must be guided so as to recognize the flood-prone nature of this unusually wide strip of low-lying land along the Little Menomonee River in the City of Mequon if the creation of a serious flood problem is to be avoided.

Source: SEWRPC.

Table 38

RESULTS OF INTERVIEWS CONDUCTED IN THE CITY OF MEQUON CONCERNING THE APRIL 21, 1973 FLOOD

Universe and Sample Parameters			Overland Flooding Area	Secondary Flooding Area	Combined Area
Universe	Total Number of Major Structures (1973)		0	--[a]	--[a]
Sample Size	Number		0	17	17
	Percent of Total Number of Structures		0	--[a]	--[a]
Structure Types Based on Sample	Single-Family Residence	Number	0	15	15
		Percent of Sample	0	88	88
	Two-Family Residence	Number	0	1	1
		Percent of Sample	0	6	6
	Business-Commercial	Number	0	1	1
		Percent of Sample	0	6	6
Basement Information Based on Sample	Number with Basements		0	13	13
	Percent of Sample		0	76	76
Basement Flooding Information Based on Sample.	Attributed to Sewer Back-Up	Number	0	0	0
		Percent of Sample	0	0	0
	Attributed to Overland Flooding	Number	0	0	0
		Percent of Sample	0	0	0
	Attributed to a Combination of Above, Others, or Unknown	Number	0	2	2
		Percent of Sample	0	12	12
	Total Basement Flooding	Number	0	2	2
		Percent of Sample	0	12	12
First Floor Flooding Information Based on Sample.	Number		0	0	0
	Percent of Sample		0	0	0

[a]*Not available.*

Source: SEWRPC.

Another type of flood-related damage and disruption reported in Mequon was agricultural. A variety of crops including corn, melons, potatoes, mixed vegetables, and sod for lawns is grown in the broad, low-lying lands along the Little Menomonee River. The rich floodland soils are used intensively in that the land is planted almost to the edge of the Little Menomonee River. As a result of standing water and extremely wet conditions following the flood, farmers encountered some difficulty operating tractors and other equipment in the floodland area and spring planting was delayed. Some of the seeds that had already been planted were washed away by the floodwaters. Farmers in the area noted that, of all crops, mature corn because of its height is best able to withstand several days of inundation during summer and fall floods.

Village of Germantown: The Menomonee River occupied large portions of its floodlands along the Menomonee River for the entire 4.45-mile-long reach extending from County Line Road (CTH Q) upstream past the original Village area to the Chicago and North Western Railroad bridge near the center of Section 15. Overland flooding also occurred along most of the 2.21-mile-long reach of the West Branch of the Menomonee River extending from the Menomonee River upstream to Dalebrook Drive which crosses the West Branch near the southeast corner of Section 17. Overland flooding was also reported along Willow Creek in the vicinity of Appleton Avenue (STH 175) and along the upper reaches of the Nor-X-Way Channel northeast of STH 145. Map 58 shows the overland flooding along the Menomonee River, the West Branch, Willow Creek, and the Nor-X-Way Channel. The

Table 39

RESULTS OF INTERVIEWS CONDUCTED IN THE VILLAGE OF GERMANTOWN ON THE APRIL 21, 1973 FLOOD

Universe and Sample Parameters			Overland Flooding Area	Secondary Flooding Area	Combined Area
Universe	Total Number of Major Structures (1973)		0	--[a]	--[a]
Sample Size	Number		0	15	15
	Percent of Total Number of Structures		0	--[a]	--[a]
Structure Types Based on Sample	Single-Family Residence	Number	0	14	14
		Percent of Sample	0	93	93
	Multi-Family Residence	Number	0	0	0
		Percent of Sample	0	0	0
	Business-Commercial	Number	0	1	1
		Percent of Sample	0	7	7
	School	Number	0	0	0
		Percent of Sample	0	0	0
	Other Public	Number	0	0	0
		Percent of Sample	0	0	0
	Other Private	Number	0	0	0
		Percent of Sample	0	0	0
Basement Information Based on Sample	Number with Basements		0	14	14
	Percent of Sample		0	93	93
Basement Flooding Information Based on Sample.	Attributed to Sewer Back-Up	Number	0	0	0
		Percent of Sample	0	0	0
	Attributed to Overland Flooding	Number	0	0	0
		Percent of Sample	0	0	0
	Attributed to a Combination of Above, Others, or Unknown	Number	0	2	2
		Percent of Sample	0	13	13
	Total Basement Flooding	Number	0	2	2
		Percent of Sample	0	13	13
First Floor Flooding Information Based on Sample.	Number		0	0	0
	Percent of Sample		0	0	0

[a] *Not available.*

Source: SEWRPC.

delineation of the lateral extent of overland flooding shown on this map is based on the observations of flood damage survey interviewees and on recorded high water levels.

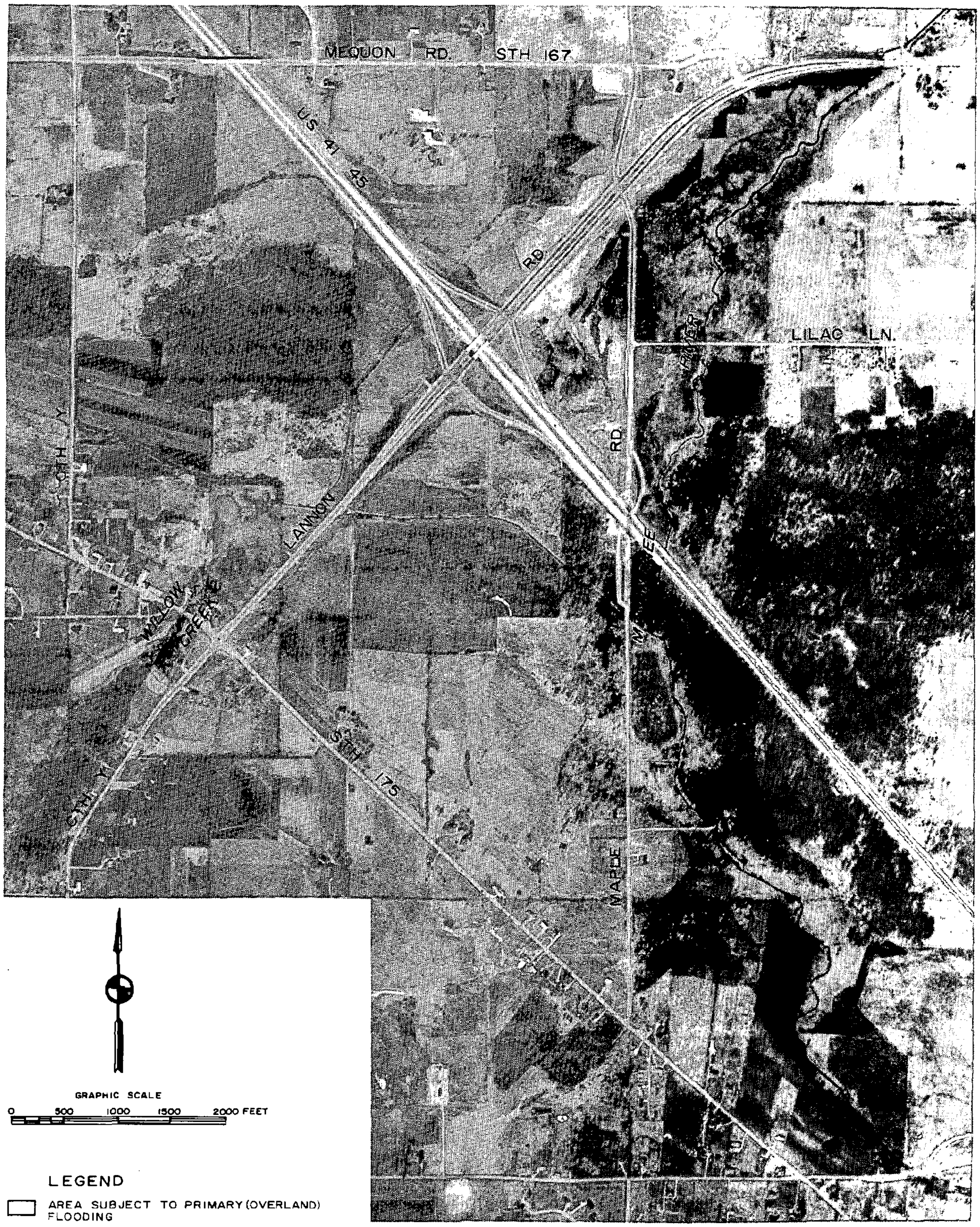
A detailed summary of the field interview findings is set forth in Table 39. According to the survey, no major structures were located within the area of overland flooding. Interviews were completed with the owners or occupants of 15 structures, including 14 single-family residences located adjacent to the overland flood area. While over 90 percent of these structures had basements, basement flooding was reported for only 13 percent of the structures included in the sample.

As shown on Map 58, there are only two developed areas in relatively close proximity to the floodlands in Germantown; the Lake Park development east of the Menomonee

Map 58

OVERLAND FLOODING ALONG THE MENOMONEE RIVER, THE NORTH AND WEST BRANCHES OF THE MENOMONEE RIVER, AND WILLOW CREEK IN THE VILLAGE OF GERMANTOWN: APRIL 21, 1973

MENOMONEE RIVER FROM SOUTH VILLAGE LIMITS TO MEQUON ROAD AND WILLOW CREEK

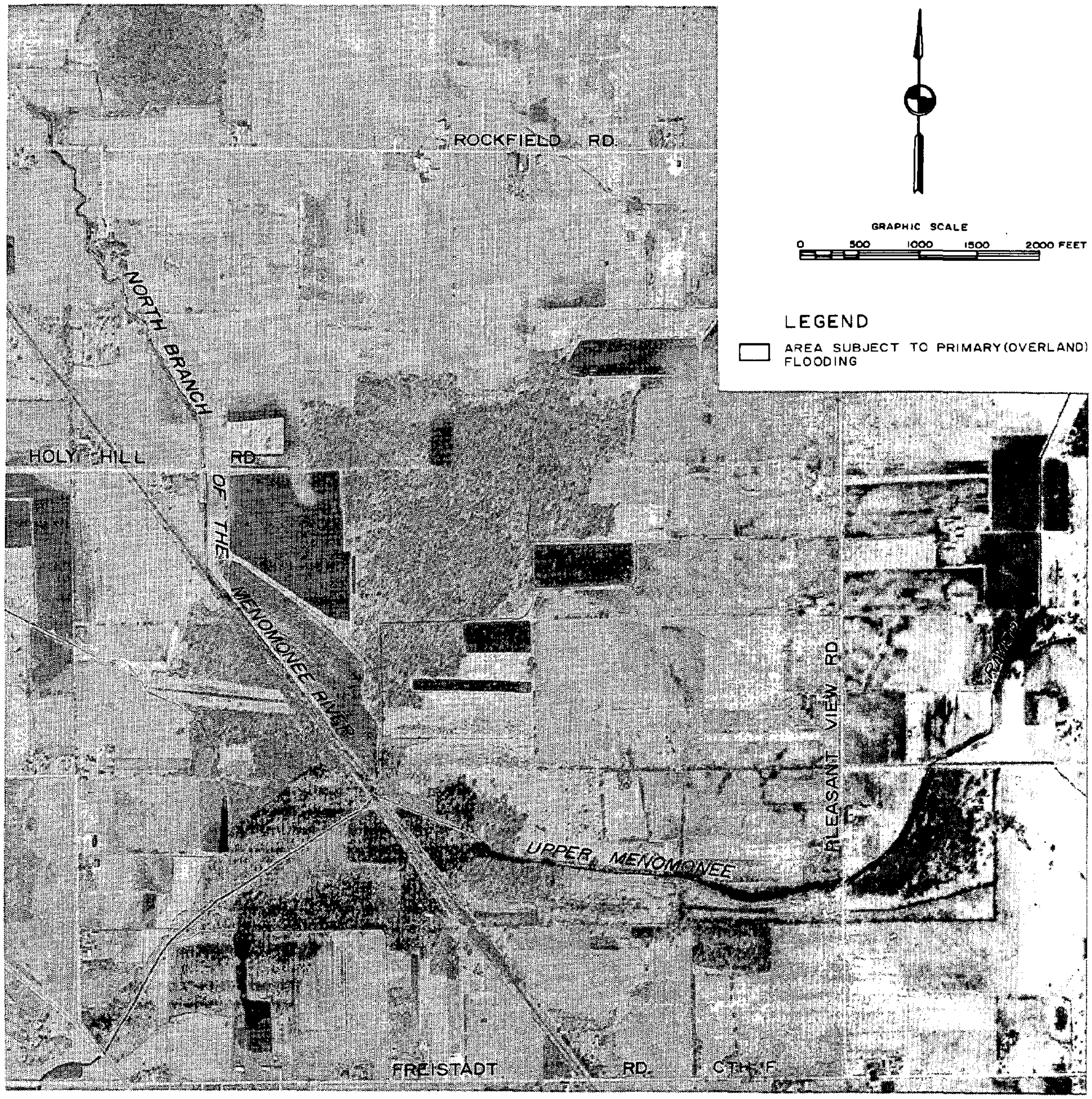


Map 58 (continued)

MENOMONEE RIVER FROM MEQUON ROAD TO STH 145 AND WEST BRANCH OF THE MENOMONEE RIVER

Map 58 (continued)

MENOMONEE RIVER NORTH AND EAST FROM STH 145 AND NORTH BRANCH OF THE MENOMONEE RIVER



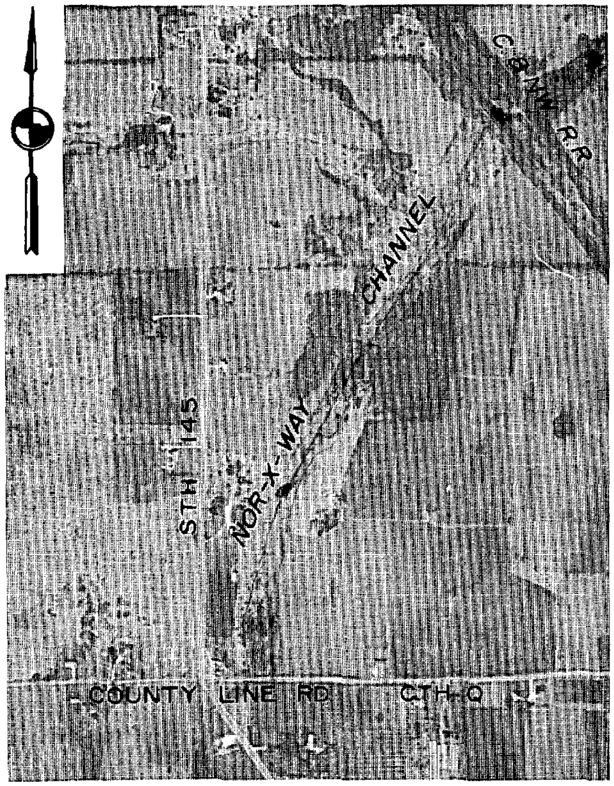
River near the original Village area and the residential-commercial area near Willow Creek west of the intersection of Appleton Avenue (STH 175) and Lannon Road (CTH Y). As indicated by the field survey, neither of these areas incurred significant flood problems in April 1973 and, in general, there were no significant structure flood problems anywhere in the Village of Germantown.

Although much of the Village of Germantown is in rural land uses, no significant agricultural flood losses or disruption were incurred, primarily because farming activities are not generally carried out in the floodland area within the Village. Many of the floodlands are composed of woodland and wetland areas in an essentially natural state.

In addition to collecting data and information relative to the April 21, 1973, flooding in the Village of Germantown, the field surveys revealed that high water levels occurred again on April 14, 1974. Based on data obtained from these surveys, it is apparent that the April 1974 flooding produced peak stages that ranged from April 21,

Map 58 (continued)

NOR-X-WAY CHANNEL



LEGEND

AREA SUBJECT TO PRIMARY (OVERLAND) FLOODING

GRAPHIC SCALE

0 500 1000 1500 2000 FEET

No significant disruption or damage occurred within the Village of Germantown as a result of the April 1973 flood for several reasons. First, there is as yet relatively little urban development in the Village and that which does exist is located outside of the natural floodlands. Second, agricultural flood losses or disruption were minimal because farming activities are not generally carried out in the floodland areas of the Village with most of the floodlands devoted to woodland and wetland areas and retained in essentially natural state. Third, rainfall amounts measured in the Germantown portion of the watershed immediately prior to and during the April 1973 flood were somewhat less than that observed in the remainder of the basin.

Source: SEWRPC.

1973, levels to as much as two feet above those levels. There were no significant flood problems reported, however, with respect to either major structures or agricultural lands because, as noted above, most of the floodlands in the Village of Germantown are not occupied by structures nor are they used for agricultural purposes.

Other Communities: Compared with its impact as measured in damage and disruption or in overland flooding in the above six communities—the Villages of Elm Grove, Menomonee Falls, and Germantown and the Cities of Wauwatosa, Brookfield, and Mequon—the April 21, 1973, flood had little impact on the other riverine area communities in the watershed. The general absence of flood problems, as defined earlier in this chapter, in these other communities is primarily attributable to the presence of structural flood control works that protected riverine area residential, commercial, and industrial development. Thus, relatively few incidences of flooding were reported along Honey Creek—which flows through parts of the Cities of Greenfield, Milwaukee, and West Allis—because of the extensive (more than 7.0 miles) channel modifications completed along Honey Creek since 1960.

A similar situation exists along the Menomonee River in the City of Milwaukee, particularly immediately upstream of and within the industrial valley. Largely as a result of channel modifications and sheet steel flood walls completed by the Milwaukee-Metropolitan Sewerage Commissions from 1962 to 1968 along the 1.5 mile reach from the Milwaukee, St. Paul and Pacific Railroad yard upstream to about 45th Street, the April 21, 1973, flood was confined to the channel area. Similarly, a sheet steel floodwall constructed along the Menomonee River by the Falk Corporation in 1962 at a cost of $400,000 prevented flooding at that location even though the peak stage of the April 21, 1973, flood was about two feet higher than the peak stage of the March 30, 1960, flood which caused extensive losses to the Falk Corporation.

It is important to recognize that there are areas in the Menomonee River watershed which continue to experience localized stormwater problems. Examples include non-riverine land in the heavily urbanized Honey Creek subwatershed, the area in the Village of Elm Grove east of the Underwood Creek floodlands and north of Watertown Plank Road, and scattered areas in the City of Milwaukee. As noted earlier in this chapter, the Menomonee River watershed planning program distinguishes between stormwater problems and flood problems. Watershed areas selected for characterization of historic flood problems, for computation of monetary flood risks and for development of alternative floodland management measures, exclude river reaches in which historic flood problems have been largely resolved and also exclude watershed areas that exhibit stormwater system deficiencies, the latter being beyond the intended scope of this planning program.

Historic Flooding: Some Observations

As already noted in this chapter, one of the six uses of historic flood information is to support public educational and informational activities after completion of the watershed plan. To support these activities much can be learned and several conclusions can be drawn from the record of historic flooding in the Menomonee River watershed. Some observations based on information obtained during the research on historic flooding are discussed below. The intent is that these observations may be useful to public officials and interested citizens when they face decisions directly or indirectly related to development or redevelopment in the riverine areas, particularly decisions related to flood problems.

Correlation Between Urban Growth and Flood Severity: A definite correlation exists between the spatial extent of urban growth in the Menomonee River watershed since about 1900 and the extent of the watershed stream system that incurred flood damage and disruption during each of the seven major flood events identified in the historic flood inventory. This correlation is clearly illustrated by a comparison of Map 9, which shows historic urban growth in the Menomonee River watershed for the period 1850 through 1970, with Maps 47, 48, 49, and 51 which delineate known flood problem areas in the watershed for the seven major flood events beginning with the flood of March 1897 and extending to the flood of April 1973. These maps, as well as Table 33, clearly show that the expansion in urban development was closely followed by an increase in the length of riverine area experiencing flood problems. The primary cause of the correlation between urban growth and severity of flooding is the failure to adjust land use development in floodland areas to the natural floodwater conveyance and storage functions of those areas.

The flood problem areas identified in the historic record are generally located where flood-prone residential, commercial, and industrial structures have been allowed to develop in the floodlands. Repeated disruption of arterial highways as a result of floodwater inundation and actual damage to river crossings suggests inadequate consideration of hydraulic factors in the planning and design of such facilities.

A possible secondary cause of the correlation between urban growth and the extent of flooding is the conversion of lands located outside of the floodlands but in the tributary watershed area from rural to urban uses. As discussed in Chapter V, "Hydrology and Hydraulics," such conversion—if carried out without providing for compensatory detention storage or other similar structural flood control measures—may be expected to increase downstream flood discharges and stages. Streamflow records for the Menomonee River watershed are not of sufficient duration to permit a quantitative analysis of the effect of historic urban development on the watershed's flood flow regime. Because of the extensive amount of urban development that has occurred in the watershed over the period for which information on major floods is available—1897 to 1973—it is reasonable to conclude that such development outside of the natural floodlands has increasingly contributed to the severity of watershed floods. Chapter IV, Volume 2, of this report presents the results of simulation studies intended to show the hydrologic, hydraulic, and flood damage effects of various combinations of floodland development and of land use outside of the floodland areas. These studies show that flood flows, stages, and corresponding flood damages are markedly affected by land use both within and outside of the watershed floodland areas.

Although there has been a historical correlation between urban growth and the severity of flood losses in the Menomonee River watershed, it does not necessarily follow that such a correlation must continue in the future. One of the available alternatives is to retain still—undeveloped floodland areas in essentially natural, open space uses compatible with occasional inundation. This approach has been followed along some reaches of the Menomonee River watershed stream system, the prime example is the continuous Milwaukee County parkland lying along portions of the Menomonee River, the Little Menomonee River, Underwood Creek, and Honey Creek. The inventory of historic flooding indicates that these areas have been repeatedly inundated with relatively little or no damage.

If, on the other hand, certain communities permit urban development to occur in flood-prone areas, that development should be planned, designed, and constructed for protection against flood damage. Available protective measures range from floodproofing of individual structures or facilities to major structural works such as earthen dikes, concrete floodwalls, and upstream reservoirs for temporary storage of floodwaters. Provision of such protective measures will, or course, add to the cost of floodland urban development. The watershed is replete, however, with examples of the consequences, including the monetary costs, of permitting urban development without providing the necessary flood protection.

Variety of Damage and Disruption: The historic record clearly demonstrates that floodwaters can cause physical damage to many different structures and facilities and in a variety of ways. As a result of that damage, and sometimes even in the absence of actual physical damage, major floods can cause significant disruption of activities throughout much of the watershed.

The principal type of damage experienced in the Menomonee River watershed has been damage to structures—private residences, commercial and industrial buildings, and public buildings—and to their contents as a result of overland and attendant secondary flooding. Bridges and culverts and sections of roadways have been damaged by the erosive action of rapidly moving floodwaters so as to require extensive repair or complete rebuilding. In several incidents materials stored in floodland areas have been damaged as a result of inundation or have been buoyed up on the rising floodwaters and carried away. Scattered instances of damage to shrubs, grass, and other landscaping as a result of erosion or prolonged inundation have also been reported.

A common and costly type of disruption associated with major flood events in the Menomonee River watershed has been interruption of manufacturing and business activities not only during flood events but also during the post-flood cleanup and repair period. In the public sector, the routine operations of governmental units usually are disrupted during flood events as public officials attempt to provide immediate relief to affected areas. Another form of disruption directly attributable to major flood events is the temporary closure of highways and railroads that have been inundated at a relatively low place, such as an underpass, or as a result of damage to a river crossing. Although floodland recreational areas and facilities such as ball fields, golf courses, and picnic grounds typically incur little physical damage as a result of flooding, their use is temporarily curtailed by inundation.

In summary, then, the historic flood record assembled for the Menomonee River watershed reveals that floods cause physical damage to many types of structures and facilities in a variety of ways, and that floods directly or indirectly disrupt the normal activities of many watershed residents. While the physical damage caused by major flood events is limited to the riverine areas, the attendant costs may be more widely borne. The disruption of community activities also has a widespread effect in that such disruption is experienced not only by riverine area occupants but by other residents of the watershed and Region that frequent the floodland areas for business, employment, recreational, or other purposes.

Dominance and Significance of Rainfall-Induced Flood Events: Chapter V of this report, entitled "Hydrology and Hydraulics," presents data drawn from the period of daily streamflow records in the watershed—water years 1962 through 1973. These records clearly indicate that rainfall, as opposed to either snowmelt or a combination of rainfall and snowmelt, has been the dominant cause of annual flood events in the Menomonee River watershed. This conclusion is further substantiated by the historic record for major floods prior to the period of daily streamflow recordation. Of the four major floods—March 18, 1897; June 22, 1917; June 23, 1940; and March 30, 1960—contained within this period, three were exclusively rainfall events while the fourth, the March 30, 1960 flood, was a combination rainfall and snowmelt event. Furthermore, rainfall has been the causative factor for all three of the major historic flood events occurring since daily stream flow records began.

The dominance of rainfall event floods in the Menomonee River watershed is significant for two reasons. First, with the exception of the winter season, major floods can occur any time of the year. Second, rainfall floods, as opposed to either snowmelt or combination rainfall-snowmelt floods, will exhibit rapid increases in stream discharge and stage, especially in the typical hydraulically efficient urban environment, thereby providing little opportunity for communicating flood warnings to occupants of riverine areas. The historic flood record contains numerous examples, like that shown in Figure 54, of the flashy response of the urban Menomonee River watershed to rainfall events.

The Risk to Human Life and Health: There is a tendency to consider and evaluate the damage and disruption normally accompanying flooding without due regard to the risk to human life and health that exists during every major flood event. Public officials and interested citizens should be aware of this danger as one factor to be weighed in making decisions that are directly or indirectly related to riverine areas.

The historic flood record for the Menomonee River watershed contains several accounts of loss of life and near loss of life directly attributable to flood conditions. As a result of rapidly rising waters during the June 1917 flood, it was necessary to rescue approximately 50 people from the flood-prone "Pigsville" area and, as a result of a similar rapid rise in the March 1960 flood, a rescue operation was conducted for about 25 workers trapped in the Falk Corporation plant in the Menomonee River industrial valley. A boy drowned in Honey Creek during the June 1940 flood and another person drowned during the July 1964 flood as a result of being trapped in a stalled car at an underpass near the Menomonee River. During that same flood, firemen rescued two boys from the Menomonee River and one boy from Honey Creek. Police and firemen used boats and rope guide lines to rescue and evacuate about 22 families from a residential area in the City of Wauwatosa during the April 1973 flood.

Regardless of the type of watershed, flood events are potentially hazardous to people in or near the riverine areas primarily because normally shallow, narrow, slow moving rivers and streams become deep, wide, rapidly moving torrents that can readily entrap even an adult. For example, floodwaters at a depth of 4 feet and moving at a velocity of 4 feet per second, a condition that would be expected over much of the natural floodlands of the Menomonee River during a major flood event, would exert a dynamic force of approximately 110 pounds on an adult. If the velocity were doubled to 8 feet per second, which is still a common condition near the channel during a major flood event, the dynamic force would increase by a factor of 4 to about 440 pounds.[3] Not only are these forces large, but they would probably be applied abruptly and unexpectedly to persons entrapped in the floodwaters.

The threat to human life is relatively more severe in the Menomonee River watershed for three reasons. First, much of the watershed is urbanized and therefore many watershed residents are in close proximity to the stream system. Second, as a result of the extensive storm and flood water conveyance system that has been developed to serve the urbanized portions of the watershed, flood discharges and stages in the watershed stream system rise rapidly, relative to a primarily rural watershed, giving little warning. Third, as discussed in Chapter V, "Hydrology and Hydraulics," about 15 miles of the watershed stream system have been subjected to major channelization and as a result, these hydraulically efficient sections will exhibit very high, and therefore, potentially dangerous channel velocities during flood events. Results obtained with the hydrologic-hydraulic model described in Chapter VIII of this report indicate that channel velocities in channelized sections may be expected to be substantially larger than channel velocities in natural riverine areas under major flood conditions. The 2.43 mile reach of the

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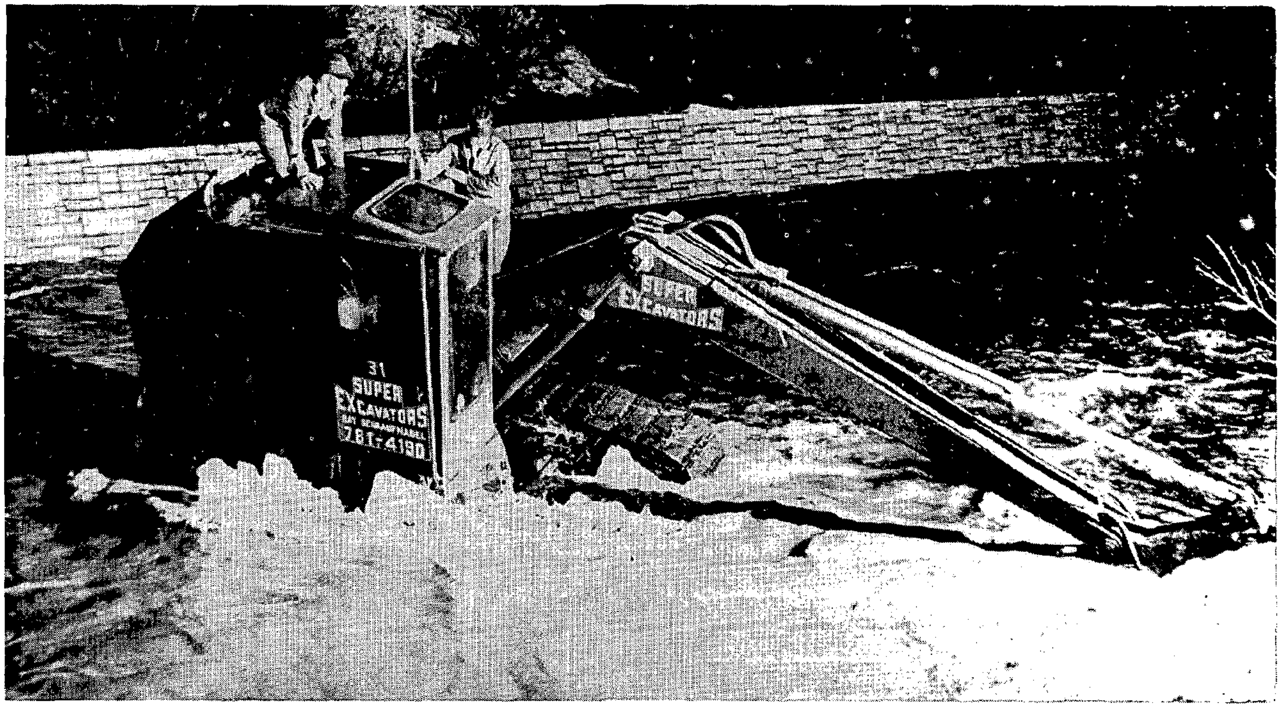
[3] *The dynamic force or drag may be computed using the equation force =* $C_D A \rho V^2/2$ *where* C_D *= dimensionless drag coefficient = 1.2, A = area of submerged surface perpendicular to flow = 4.0 feet x 1.5 feet = 6.0 square feet,* ρ *= mass density of water = 1.94 slugs per cubic feet and V = velocity of the water = 4 and 8 feet per second.*

Figure 54

BACK HOE ENTRAPPED BY RAPIDLY RISING FLOODWATERS OF THE MENOMONEE RIVER: FEBRUARY 1966



Intensive urbanization, with its accompanying drainage improvements, tends to decrease the time required for surface water runoff to be collected and conveyed and concentrated in the lower reaches of a watershed, as well as to increase the amount of runoff. Such decreases in the time of concentration tend to cause the flood flow behavior of a stream to become "flashy" with rapid uses in downstream flows and stages. This is illustrated in the photograph above, taken on February 9, 1966. What started out as a construction project to lay a water supply pipeline across the Menomonee River at N. 45th Street in the City of Milwaukee with about six inches of water in the river became a rescue project when a crane had to be called to lift the back hoe out of the rapidly rising Menomonee River.

Source: The Journal Company.

Menomonee River bounded by W. North Avenue at the downstream end and W. Capitol Drive at the upstream end has a natural channel-floodplain cross section. Hydrologic-hydraulic calculations under year 2000 plan land use-floodland development conditions indicate that the median channel velocity for cross-sections in this natural reach under 10-year recurrence interval flood event conditions would be 3.4 feet per second and under 100-year recurrence interval flood event conditions would be 3.2 feet per second. The 2.25 mile long reach of the Menomonee River bounded at the downstream end by the 27th Street viaduct and at the upstream end by 45th Street has been extensively channelized for flood control purposes. Hydrologic-hydraulic computations indicate that, under year 2000 plan land use-floodland development conditions, the 10-year recurrence interval flood event would produce a median velocity in this reach of 8.0 feet per second whereas the 100-year recurrence flood event will result in a median velocity in this reach of 10.5 feet per second. Inasmuch as these two stream reaches are similar with respect to channel bottom slopes, the large channel velocity in the channelized section compared to the natural channel-floodplain cross section is largely attributable to the hydraulic effect of channelization. Not only are velocities higher in channelized reaches compared with the conditions that exist in the channel and on the floodplain under more natural conditions, but escape from the channelized reaches is more difficult because of the relatively smooth, steep sidewalls.

In summary, then, historic evidence accumulated for the Menomonee River watershed indicates that major flood events can pose a serious threat to human life. This risk is heightened in urban watersheds like the Menomonee River watershed because of the close proximity of people to the riverine areas, the "flashy" nature of the streams, and the high velocities and steep sidewalls characteristic of channelized reaches.

While the threat of flooding to human life can be readily illustrated by the above historic accounts of flood-related rescues and deaths, the health threat is not so apparent. Nevertheless, it does exist. Floodwaters can be the medium for transporting potentially harmful substances such as toxic materials from industrial operations and pathogenic (disease-producing) bacteria from onsite waste disposal systems, sanitary sewers, combined sewers, and sewage treatment plants from their sources to residential areas where there is the possibility of contact with and harm to the residents.

In addition to potential physiological harm, the occurrence of floods as well as the ever-present threat of flooding can adversely affect the psychological health and well-being of riverine area residents. Owners or tenants of flood-prone structures and properties are burdened with the need to be in a constant state of readiness, particularly in the Menomonee River watershed where major floods can occur almost any time of the year and with little warning. These owners or tenants occasionally must contend with the unpleasant task of cleaning flood-borne sand, silt, and other materials and debris from their homes and places of business. Finally, even after the flood has passed and the cleanup and repair have been completed, lingering odors and other evidence of the recent inundation will impose an additional psychological stress on the occupants of riverine area property.

MONETARY FLOOD LOSSES AND RISKS

Flood damage may be defined as the physical deterioration or destruction caused by floodwaters. The term flood loss refers to the net effect of historic flood damage on the regional economy and well-being with the tangible components of the loss being expressed in monetary units. Flood risk is the probable damage, expressed either on a per flood event basis or on an average annual basis, that will be incurred as a result of future flooding with the tangible portion of the risk expressed in monetary terms. All losses resulting from historic flooding or the risk attendant to future flooding can be classified into one of three types of damage categories—direct, indirect, and intangible—or they can be classified according to whether the private or the public sector incurs the losses or risks. This two-way classification of flood losses and risks is set forth in Table 40.

Flood Losses and Risks Categorized by Type

In order to promote compatibility with the policies and practices of such federal agencies as the U. S. Army Corps of Engineers and U. S. Soil Conservation Service which may be asked to assist in the implementation of the recommended watershed plan, the following three categories of flood losses and risks were defined for the purpose of the study:

1. Direct flood losses or risks were defined as monetary expenditures required, or which would be required, to restore flood-damaged property to its pre-flood condition. This includes the cost of cleaning, repairing, and replacing residential, commercial, industrial, and agricultural buildings and contents and other objects and materials

Table 40

CATEGORIES OF FLOOD LOSSES AND RISKS

Category: Type of Damage / Category: Ownership	Private Sector	Public Sector
Direct	Cost of cleaning, repairing, or replacing residential, commercial, and industrial buildings; contents and land. Cost of cleaning, repairing, or replacing agricultural buildings and contents and cost of lost crops and livestock.	Cost of repairing or replacing roads, segments, bridges, culverts, and dams. Cost of repairing damage to storm water systems, sanitary sewerage systems, and other utilities. Cost of restoring parks and other public recreational lands.
Indirect	Cost of temporary evacuation and relocation. Lost wages. Lost production and sales. Incremental cost of transportation. Cost of post-flood floodproofing.	Incremental costs to governmental units as a result of flood fighting measures. Cost of post-flood engineering and planning studies and of implementing structural and nonstructural floodland management recommendations.
Intangible	Loss of life. Health hazards. Psychological stress. Reluctance by individuals to inhabit flood-prone areas thereby depreciating riverine area property values.	Disruption of normal community activities. Reluctance by business interests to continue development of flood-prone commercial-industrial areas thereby adversely affecting the community tax base.

Source: SEWRPC.

located outside of the buildings on the property. Direct losses and risks also encompass the cost of cleaning, repairing, and replacing roads and bridges, storm water systems, sanitary sewer systems, and other utilities, as well as the cost of restoring damaged park and recreational lands.

2. Indirect flood losses and risks were defined as the net monetary cost of evacuation, relocation, lost wages, lost production, and lost sales; the increased cost of highway and railroad transportation because of flood-caused detours; the costs of flood fighting and emergency services provided by governmental units, as well as the cost of post-flood floodproofing of individual structures. The costs of post-flood engineering and planning studies and of implementing the structural and non-structural measures recommended by those studies also are categorized as indirect losses and risks. Although often difficult to determine with accuracy, indirect losses and risks nevertheless constitute a real monetary burden on the economy of the Region.

3. Intangible flood losses and risks were defined as flood effects which cannot be measured in monetary terms. Such losses and risks include loss of life, health hazards, property value depreciation as a result of flooding, and the general disruption of normal community activities. Intangible losses and risks also include the severe psychological stress experienced by owners or occupants of riverine area structures. It is significant to note that, in the course of the flood damage survey, many damagees declared that the intangible damages, such as psychological stress, were the most severe flood effects they experienced, monetary costs notwithstanding.

Flood Losses and Risks Categorized by Ownership

As noted above, flood losses and risks may also be classified on the basis of ownership into public-sector and private-sector. Each of the three categories of flood loss by type—direct, indirect, and intangible—may be subdivided into public-sector and private-sector losses as shown in Table 40. Within the direct loss category, for example, the cost of cleaning, repairing, and replacing residential buildings and their contents is a private-sector flood loss whereas the cost of repairing or replacing damaged bridges and culverts is a public-sector loss.

Role of Monetary Flood Risks

Previous sections of this Chapter identified the major historic flood events known to have occurred within the watershed and described the severity of each flood event in terms of the reaches of the stream system affected, the types of damage and disruption that occurred, the relative magnitude of recorded discharges and observed stages, and the degree to which human life was endangered. While such a qualitative or semi-quantitative description of flooding is an effective means of communicating the characteristics of flooding, it is not adequate for sound economic analyses of alternative solutions to flood problems. Such analyses require that flood damages for the various stream reaches be quantified in monetary terms on a uniform basis applied throughout the watershed.

The quantitative, uniform means of expressing flood damages selected for use in the Menomonee River Watershed Study was the average annual flood damage risk expressed in dollars. Average annual flood risk was computed for flood-prone reaches to provide a monetary value that could be used, wholly or in part, as an annual benefit for comparison to annual costs of technically feasible alternative flood control plan elements such as acquisition and removal of flood-prone structures, structure floodproofing, channel modification, and construction of earthen dikes, concrete floodwalls, and flood control reservoirs.

Methodology Used to Determine Average Annual Flood Risks

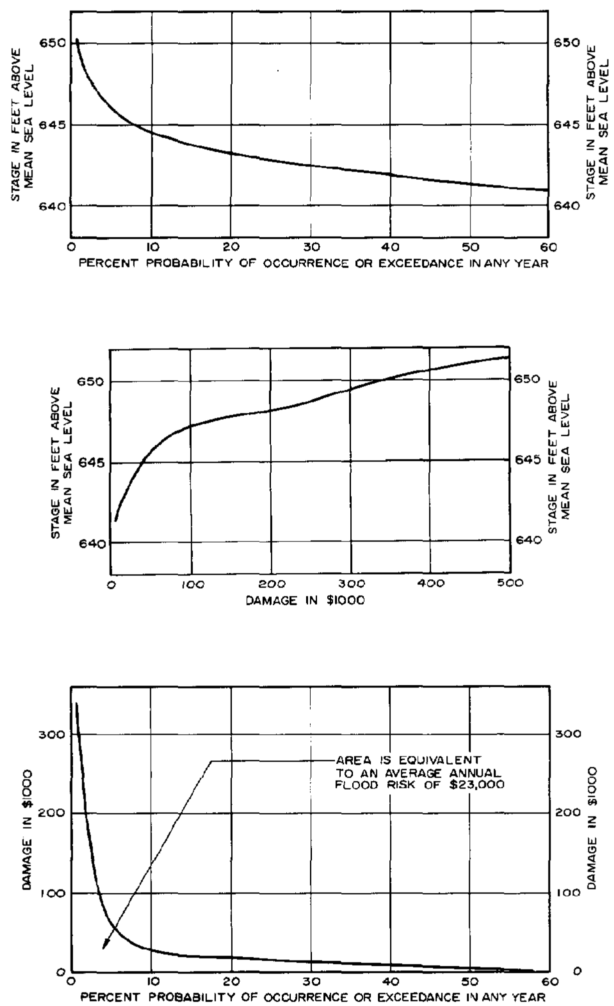
The average annual flood damage risk for a reach is defined as the sum of the direct and indirect monetary flood losses resulting from floods of all probabilities, each weighed by its probability of occurrence or exceedance in any year. If a damage-probability curve is constructed, such as the graph of dollar damage versus flood probability as illustrated in Figure 55, the average annual risk is represented by the area beneath the curve. The damage-probability curve for each flood-prone reach is developed by combining the reach stage-probability relationship with the reach stage-damage curve as illustrated in Figure 55. The determination of average annual flood risk for a particular flood-prone reach, therefore, is dependent upon construction of the stage-probability and stage-damage relationships for the reach.

The ideal way to develop the two required relationships for a particular reach would be to have a long series of stage observations which could be analyzed statistically to yield the stage-probability curve and a similar long series of direct and indirect damages actually experienced by riverine area occupants for a full range of flood stages which could be used to construct a stage-damage curve. Inasmuch as neither the river stage information nor the damage information is generally available, it is necessary to develop the stage-probability and stage-damage relationships by analytical means and then to combine them to form the damage-probability relationship.

Synthesis of Reach Stage-Probability Relationships: The stage-probability relationship for a particular reach is determined by the hydraulic characteristics of the reach, such as the shape of the floodland cross-sections, the value of the Manning roughness coefficients and presence of bridges, culverts, and other structures—all of which are to some extent determined by the activities of man—and the magnitude of flood flows expected in the reach. These flood flows are in turn a function of upstream hydraulics and hydrology which are also, because of man's activities, continuously undergoing change or have the potential to do so. It follows, therefore, that each reach does not have a unique stage-probability curve but

Figure 55

EXAMPLE OF CURVES USED TO DETERMINE AVERAGE ANNUAL FLOOD RISK FOR A RIVER REACH



NOTE: EXAMPLE PERTAINS TO FLOOD DAMAGE FOR THE MENOMONEE RIVER REACH BETWEEN N. 71ST STREET AND N. 73RD STREET EXTENDED IN THE CITY OF WAUWATOSA.

Source: SEWRPC.

instead there are many possible stage-probability curves, each of which is associated with a given combination of hydrologic-hydraulic conditions in and upstream of the reach in question.

A digital computer hydrologic-hydraulic model was used to simulate stage-probability curves for selected reaches throughout the watershed. As described in Chapter VIII of this report, "Water Resources Simulation Model," this model was used to prepare stage-probability curves for the hydrologic-hydraulic conditions representing existing land use, planned land use, and other alternative land use configurations. Figure 55 shows an example of a stage-probability curve synthesized with the digital computer model.

Synthesis of Reach Stage-Damage Relationships: The stage-damage curve for a reach is determined by the nature and extent of flood-prone structures and other property contained within the reach. It follows, therefore, that there is a separate stage-damage curve for each combination of riverine area land uses. Development of the stage-damage relationship for a particular combination of riverine area land uses in a reach begins with computation of the flood losses that may be expected for an arbitrarily selected flood stage slightly above the elevation of the river channel. These flood losses consist of estimates of the direct and indirect monetary flood losses set forth in Table 40. Upon completion of the summation of flood losses at the initial flood stage, a higher stage is considered. This process is repeated so as to consider the full spectrum of flood stages from just above the river bank to well above the 100-year recurrence interval flow stage with the upper limit being determined by the hydrologic-hydraulic model of the watershed. Figure 55 presents an example of a synthesized stage-damage curve for a reach.

Synthesis of reach stage-damage relationship requires the use of stage-damage relationships for the various types structures, facilities and activities likely to be present in or to occur in floodlands. A stage damage relationship for a particular type of structure is a graph of depth of inundation in feet relative to the first floor versus dollar damage to structure and contents expressed as a percent of the total dollar value of the structure and its contents. The stage-damage relationships for five types of structures as used in the Menomonee River watershed study are shown in Figure 56. These stage-damage relationships were developed by the Commission staff using Federal Insurance Administration tables as published in 1970 and revised in 1974 and 1975.

Determination of Indirect Damages: The above stage-damage relationships reflect the direct damage to each of the various types of structures as the function of the depth of inundation. Indirect damages, which can be a significant fraction of the total monetary losses incurred during a flood event, were computed as a percentage of the direct damages to the various types of structures. The direct damages to commercial and industrial structures were increased by 40 percent to account for indirect damages whereas the direct damages to residential and all other types of structures were increased by 15 percent to reflect indirect damages.[4]

Average Annual Flood Risks for Selected Reaches

The above methodology was used to compute average annual flood risks for selected reaches in the Menomonee River watershed under existing and hypothetical future floodland development-land use conditions. The voluminous computations were carried out with the flood

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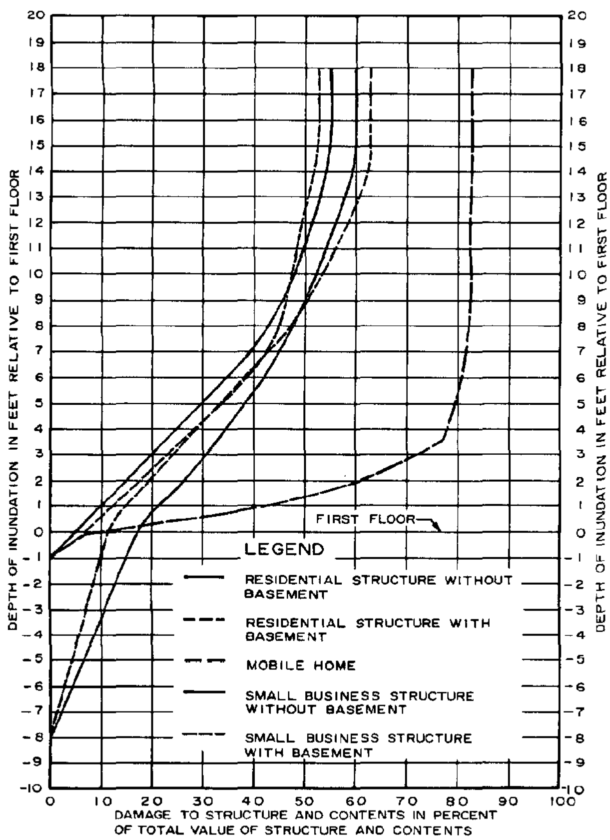
[4] *Kates, R. W., "Industrial Flood Losses: Damage Estimation in the Leheigh Valley," the University of Chicago, Department of Geography, Research Paper No. 98, pages 15 to 17, 1965.*

Figure 56

DEPTH-DAMAGE CURVES FOR SELECTED STRUCTURES



Source: Federal Insurance Administration and SEWRPC.

economics submodel described in Chapter VIII of this volume. The resulting per event and average annual flood risks for selected reaches under variety of conditions are presented in tabular and graphic form in Chapter IV, Volume 2, of this report.

SUMMARY

An understanding of the interrelationships that exist between the flood characteristics of the watershed stream system and the urban and rural uses to which the riverine areas of the watershed are put is fundamental to any comprehensive watershed study. This understanding is a prerequisite furthermore to solving existing flood problems and preventing the occurrence of future flood problems. Flood damage and disruption in the Menomonee River watershed have been largely a consequence of the failure to recognize and account for the relationships which exist between the use of land, both within and outside of the natural floodlands of the watershed, and the flood flow behavior of the stream system of the watershed.

Within the overall objective of contributing to an improved understanding of the interrelationship between watershed land use and flooding, this chapter has two purposes. First, the chapter reviews historic flood information and, second, the chapter describes the procedure used to compute monetary flood risks under existing and alternative future land use conditions. Historic flood information has several key applications during both the plan preparation and plan implementation processes including: identification of problem areas, determination of the causes of flooding, calibration of the hydrologic-hydraulic model, computation of monetary flood risks, formulation of alternative flood control plan elements, and post-plan information and education purposes. Synthesized monetary flood risks are utilized during the watershed planning process to conduct cost-benefit analyses of alternative flood control plan elements such as acquisition and removal of flood-prone structures, structure floodproofing, channel modification and construction of dikes, floodwalls and flood control reservoirs.

A distinction is drawn between flooding, which is the intended concern of this chapter and one of the major water resource problem areas being addressed in the watershed planning effort, and storm water problems which are beyond the scope of the Menomonee River watershed planning program. Flood problems are defined, for purposes of this report, as damaging inundation which occurs along well defined rivers and streams as the direct result of water moving out of and away from those rivers and streams, and includes both overland and secondary flooding. In contrast, stormwater drainage problems are defined as damaging inundation which occurs when stormwater runoff enroute to rivers and streams and other low-lying areas encounters inadequate conveyance or storage facilities and, as a result, causes localized ponding and surcharging of storm and sanitary sewers.

Research of the historic record revealed the occurrence of seven major floods in the Menomonee River watershed. These major floods, each of which caused significant damage to property as well as disruption of normal activities, were the floods of March 19, 1897; June 22, 1917; June 23, 1940; March 30, 1960; July 18, 1964; September 18, 1972; and April 21, 1973. The most serious of these floods was also the most recent, the April 21, 1973, event. Based on an analysis of streamflow records available for the Menomonee River at Wauwatosa since October 1961, the July 1964, September 1972, and April 1973 floods had recurrence intervals of 7, 9, and 95 years, respectively. Information about the cause and effect of each of these floods was derived by a research process consisting of the following sequential steps: initial reconnaissance of published reports and data, review of newspaper accounts and newspaper files, examination of library and historical society holdings, meetings with community and agency officials and, where warranted, personal interviews with the owners or tenants of riverine area residential, commercial, and industrial structures and property.

In addition to the quantitative data derived from the inventory of historic flooding, several observations emerge regarding the characteristics of flooding in the Menomonee River watershed. A close correlation evident between urban growth in the watershed and the severity of flooding is attributable to the failure to adjust land uses and activities in floodland areas to the natural floodwater conveyance and storage functions of those areas. The historic record also indicates that flooding has caused physical damage to many different types of structures and facilities in a variety of ways and that the disruption attendant to major floods is experienced by many watershed residents, not just those that actually occupy the floodlands. The inventory of historic flooding reveals that rainfall, as opposed to snowmelt or rainfall-snowmelt combinations, has been the principal cause of major floods. This is particularly significant to the urban and urbanizing Menomonee River watershed because it means that, with the exception of the winter season, major floods can occur any time of the year and, when they do occur, they will be characterized by rapid increases in discharge and stage, thereby offering minimal opportunity for warning occupants of riverine areas. Finally, the risk to human life is illustrated in the historic flood record by several accounts of near drownings or drownings, with the threat to human life appearing to be more severe in an urban, rather than a rural, watershed.

Flood loss refers to the net effect of historic flooding on the regional economy and well-being with the tangible portions of the loss being expressed in monetary terms. Flood risk is the probable damage, expressed either on a per flood event basis or on an average annual basis, that will be incurred as a result of future flooding with the tangible portion expressed in monetary terms. All flood losses and risks may be classified into one of three categories—direct, indirect, and intangible—or they may be classified by whether the private or public sector incurs the losses or risks.

Average annual flood damage risk expressed in monetary terms was selected as the quantitative, uniform means of expressing flood severity in the Menomonee River watershed. These values were derived from damage-probability curves developed for selected reaches under existing, planned, and other alternative land uses.

Chapter VII

WATER QUALITY CHARACTERISTICS AND PROBLEMS

INTRODUCTION

One of the basic premises underlying the Commission watershed studies is that the activities of man affect, and are affected by, water quality. This is especially true in a highly urbanized watershed such as the Menomonee River watershed where the effects of human activities on water quality tend to overshadow natural influences. The hydrologic cycle provides the principal linkage between human activities and the quality of surface and ground waters in that the cycle transports potential pollutants from man to his environment and from the environment to man.

Water resources planning efforts in general, and the Menomonee River watershed planning program in particular, must include an evaluation of historic, present and anticipated future conditions of water quality and of the relationship of water quality to existing and probable future land and water uses. This chapter describes historic and existing water quality conditions in the Menomonee River watershed and identifies the nature and cause of surface and ground water pollution problems that exist or are developing in the watershed. More specifically, this chapter discusses the concepts of water quality and pollution; describes the characteristics and significance of key water quality indicators; summarizes water quality objectives and supporting standards for the surface water system of the watershed; documents the location and type of various sources of waste waters and other potential pollutants and the characteristics of the resulting discharges; describes the historic and existing quality of the surface and ground water resources, and presents an overview of water supply systems and associated problems. Data and information presented herein provide the basis for the development and testing of alternative water quality control plan elements described in Volume 2 of this report.

WATER QUALITY AND POLLUTION: BACKGROUND

The term "water quality" refers to the physical, chemical, and biological characteristics of surface and ground water. Water quality is determined both by the natural environment and by the activities of man. The uses which can be made of the water resource are significantly affected by its quality, and each potential use requires a certain level of water quality.

Definition of Pollution

Pure water, in a chemical sense, is not known to exist in nature in that foreign substances, originating from the natural environment or the activities of man, will always be present. Water is said to be polluted when those foreign substances are in such a form and concentration so as to render the water unsuitable for any desired beneficial uses such as the following: preservation and enhancement of fish and other aquatic life, water-based recreation, public water supply, industrial water supply and cooling water, and aesthetic enjoyment.

This definition of pollution does not explicitly consider the source of the polluting substance which may significantly affect the meaning and use of the term. For the purpose of this report, the causes of pollution are considered to be exclusively related to human activity. Examples of potentially polluting discharges to the surface waters that are related to human activities include discharges of treated effluent from municipal and private sewage treatment facilities, discharges of raw sewage from separate and combined sewer overflows and from commercial and industrial establishments, and runoff from urban areas and from agricultural lands. Any substance present in such quantities as to adversely affect certain beneficial water uses but derived from natural sources would not be herein defined as pollution but would constitute a natural condition that impairs the usefulness of the water.

Types of Pollution

As defined above, water pollution is the direct result of human activity in the tributary watershed. Water pollution may be divided into one or more of the following seven types in accordance with the nature of the substance that causes the pollution:

1. Toxic pollution, such as that caused by heavy metals and other inorganic elements or compounds in industrial wastes, some of which may be toxic to humans as well as to aquatic life;

2. Organic pollution, such as that caused by oxygen-demanding organic compounds in domestic sewage which may severely affect fish life;

3. Nutrient pollution, such as that caused by an overabundance of plant nutrient substances such as nitrogen and phosphorus compounds in urban or agricultural runoff; this type of pollution may cause unsightly, excessive plant growths which can deplete oxygen supply in the water through respiratory and decay processes;

4. Pathogenic or disease-carrying pollution, such as caused by the presence of bacteria and viruses in domestic sewage which may transmit infectious diseases from one person to another;

5. Thermal pollution such as that caused by heated discharges which may adversely affect aquatic flora and fauna.

6. Sediment pollution, such as that caused by lack of soil conservation practices in rural areas and inadequate runoff control during construction in urban areas which results in instream sediment accumulation that has the potential to inhibit fish reproduction and interfere with navigation.

7. Aesthetic pollution which could be associated with any combination of the above along with floating objects and unsightly accumulations of trash along stream banks and lakeshores.

All of the above seven types of water pollution regularly occur in surface waters. Groundwater pollution is normally limited to chemical and pathogenic pollution. With the exception of thermal pollution, all of the above types of pollution have occurred in the Menomonee River watershed as documented in this chapter.

The Relative Nature of Pollution

The determination of whether or not a particular surface or ground water resource is polluted is a function of the intended use of the water resource, in that the water may be polluted for some uses and not polluted for others. For example, a stream that contains a low dissolved oxygen level would be classified as polluted for the use of sport fishing since the survival and propagation of fish depends upon an ample supply of dissolved oxygen. That same stream, however, would not necessarily be polluted for the use of industrial cooling. Water pollution, therefore, is a relative term, depending on the uses or needs that the water is to satisfy and the quality of the water relative to the minimum requirements established for those uses or needs.

WATER QUALITY PARAMETERS

There are literally hundreds of parameters, or indicators, available for measuring and describing water quality, that is, its physical, chemical, and biological characteristics. A list of these indicators would include all of the physical and chemical substances in solution or suspension in water, all the macroscopic and microscopic organisms in water, and the physical characteristics of the water itself. Only a few of these hundreds of indicators, however, are normally useful in evaluating wastewater quality and natural surface water quality and in indicating pollution. Selected indicators were employed in the Menomonee River watershed planning program to evaluate surface and ground water quality by comparing it to supporting adopted water use standards and for describing the quality of municipal sewage treatment plant effluents and diffuse source runoff and determining the effect of those discharges on receiving streams. These indicators in the order of the following discussion are: temperature; dissolved solids; undissolved solids; hydrogen ion concentration; chloride; dissolved oxygen; carbonaceous biochemical oxygen demand; nitrogenous biochemical oxygen demand; coliform bacteria; nutrients; aquatic flora and fauna; heavy metals; organic pesticides; iron and manganese; sodium; bicarbonate, carbonate, and alkalinity; calcium, magnesium, and hardness; sulfate; fluoride; and nitrate and nitrite. The following indicator-by-indicator discussion is more than a glossary of water quality terms because it not only defines each indicator but also discusses its significance to water use.

Temperature

Temperature levels in surface waters are determined by the natural environment, primarily solar radiation and atmospheric temperature, and by wastewaters that are discharged to the surface waters at a temperature different than the ambient temperature. In southeastern Wisconsin, natural climatic temperature conditions do not raise water temperatures sufficiently high to significantly affect most uses of the water. Waste discharges such as spent cooling water, however, can raise the temperature of surface waters sufficiently high to preclude other water uses. Groundwater temperatures, in contrast to surface water temperatures, exhibit very little temporal or spatial change because the aquifer material insulates the subsurface water from fluctuating external influences.

Water temperature is important for many uses. It affects the palatability of water drawn from surface and ground water sources for human consumption and it also determines the value of water for certain industrial uses, including cooling. More importantly, however, aerobic and anaerobic biochemical processes fundamental to the operation of conventional activated sludge and trickling filter units at sewage treatment plants, as well as similar processes occurring in stabilization lagoons and naturally in surface waters, are temperature-dependent, since reaction rates approximately double with each 20°F rise in temperature within the temperature range normally encountered. Furthermore, an ample supply of oxygen is critical to aerobic sewage treatment processes as well as aerobic natural self-purification processes. That supply of oxygen available for such processes is a function of oxygen solubility in water which, in turn, is highly dependent on temperature. Finally, extremely high temperatures or rapid fluctuations in temperature can be detrimental to fish and aquatic life. As a result, the adopted water quality standards supporting the fish and aquatic life water use objective specify that the surface water temperature shall not exceed 89°F and that there shall be no abrupt temperature changes that may adversely affect aquatic life.

Dissolved Solids

The dissolved solids content of water and wastewater consists of all inorganic and organic substances that occur dissolved in the water regardless of source. Excluded by this definition are suspended organic or inorganic materials, floating organisms, and dissolved gases.

The concentration of dissolved solids in natural surface waters normally exhibits a wider variation than does the dissolved solids content of sanitary sewage. For example, surface water quality data for the Menomonee River watershed indicate concentrations of dissolved solids in the streams of the watershed ranging from a minimum of about 300 mg/l to a maximum of approximately 1,900 mg/l. Sanitary sewage composed primarily of domestic wastes may be expected to have a dissolved solids concentration of about 500 mg/l—a concentration that approximates the average dissolved solids level of the watershed's surface waters. With respect to origin, the dissolved solids found in surface waters may be traced to point waste sources, groundwater discharge, and surface runoff during rainfall or rainfall-snowmelt events.

The dissolved solids content of surface and ground water has an important bearing upon its suitability for several water uses. Water quality standards supporting adopted State of Wisconsin water use objectives specify that surface waters used as a source of municipal water supply should contain a monthly average of 500 mg/l or less of dissolved solids and shall not exceed 750 mg/l at any time. Quality standards with respect to dissolved solids content of water used for the manufacture of carbonated beverages, food canning, food equipment washing, and general processing are generally higher than for overall industrial and cooling water use and even higher than for drinking water use. Many factors are interrelated in determining the suitability of water for irrigation, important among which are the type of crop, the soil composition, drainage conditions, and climate. Water containing up to 2,000 mg/l of dissolved solids is probably suitable for irrigation purposes in southeastern Wisconsin.

Undissolved Solids

Undissolved solids—also sometimes referred to as suspended solids or sediment—consist of all the settleable and colloidal materials present in surface water, groundwater, and wastewater. These solids are either volatile (organic) or fixed (mineral), and their concentration generally increases with the degree of pollution.

Sanitary sewage composed primarily of domestic waste may be expected to contain about 200 mg/l of undissolved solids. Some of the volatile and fixed solids in sanitary sewage are settleable and in sewage treatment plants are removed in first-stage sedimentation. In subsequent biological treatment, undissolved organic matter is available as food for bacteria, protozoa, and fungi either in the undissolved state or after conversion to soluble forms. These bacteria, protozoa, and fungi grow either on trickling filter media or in suspension in the activated sludge process. A cumulative suspended solids removal in excess of 90 percent is possible in a well-operated secondary sewage treatment plant.

Another important source of undissolved material is erosion from land surfaces during rainfall and rainfall-snowmelt events. Falling rain and flowing water dislodge solid materials, transport them overland and deliver them to the surface water system. These undissolved solids, more commonly referred to as sediment, settle out or are carried in colloidal or suspended form from the watershed.

While erosional processes operate in both the rural and urban portions of a watershed, the rate of erosion in a particular precipitation regime, as measured in terms of tons of solids per acre per year, varies markedly as a function of land slope, land use, and cover. Erosion rates are generally lowest in natural areas, well-managed agricultural areas, and developed urban areas where the erosion rate generally ranges from 1.0 to 3.5 tons per acre per year. Areas undergoing construction exhibit markedly higher erosion rates of 50 to 200 tons per acre per year.[1,2] Therefore, depending on the land characteristics and the nature of the construction activity, the erosion rates for an area undergoing development can increase by a factor of about 200. In considering the potential impacts of this dramatic increase in erosion rates, it is important to note that the higher rates associated with construction usually only apply to a very small portion of the watershed land surface at any given time.

For watershed planning purposes, a distinction is drawn between erosion rates and sediment yield in that the latter is defined as the percentage of the eroded material that is actually transported from the watershed. For the 12 major watersheds contained wholly or partly in southeastern Wisconsin, which range in size from about 10 to 1,000 square miles, the yield may be expected to vary from approximately 30 percent for the smaller basins to as low as about 10 percent for larger basins.[3]

The discharge of undissolved solids from either point or diffuse sources is of concern in water quality management for a variety of reasons. The volatile or organic component of the undissolved solids discharged from a sewage treatment plant may produce excessive oxygen demand on the receiving waters, thereby producing fish kills, odors, and generally noxious conditions. Undissolved solids in sewage treatment plant effluent and land surface washoff may result in excessive color and turbidity in the receiving stream and may be detrimental to fish by causing abrasive injuries, obstructing respiratory passages, and covering and thereby damaging or destroying eggs in spawning areas. Commercial shipping and recreational boating may be impaired as a result of the accumulation of sediment in harbor areas and in the stream channels. Finally, solids eroded from the land surface provide one of the key mechanisms by which plant nutrients and adsorbed pesticides are transported from agricultural lands to the surface water system.

Hydrogen Ion Concentration

The hydrogen ion concentration of a solution is expressed in pH units which are equal to the common (base 10) logarithm of the reciprocal of the hydrogen ion con-

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[1] *Chen, Charng-Ning, "Planning Tools for Erosion Control in Urbanizing Watershed," Proceedings of the Research Conference on Urban Runoff Quantity and Quality—1974, co-sponsored by the Engineering Foundation and the ASCE Urban Water Resources Research Council, ASCE, New York, 1975, pp. 159-165.*

[2] *An erosion rate of 200 tons per acre per year is equivalent to about 1.1 inches of erosion from the land surface assuming that the dry unit weight of the natural soil is 100 pounds per cubic foot.*

[3] *Chen, Charng-Ning, op. cit.*

centration. The pH scale ranges from 0 to 14, with 7.0 identifying the neutral point separating acids with values of less than 7.0 from bases or alkaline substances with values of more than 7.0.

The hydrogen ion concentrations of water or wastewater is dependent upon the dissolved substances, both solids and gases, that occur in the water. The streams of the Menomonee River watershed, which generally exhibit pH values near or slightly above 7.0, are characteristically calcium bicarbonate waters that act as chemical buffers tending to neutralize both acids and bases. Most domestic sewage is neutral or slightly basic, whereas many industrial wastes are markedly acid or basic. Such municipal and industrial waste discharges can alter the pH of the stream depending on the complex of chemical, physical, and biological conditions that exist separately in the receiving water and in the waste discharge and that combine to interact upon blending of these waters.

A pH range of 5.0 to 9.0 for the stream-wastewater mixture is generally favorable for the biological decomposition of organic substances. Extreme pH levels or sudden changes in pH have detrimental effects on fish and aquatic life. Water quality standards supporting adopted water use objectives in Wisconsin specify that surface waters should have a pH in the range of 6.0 to 9.0 to be suitable as a source for public water supply and for fish and aquatic life uses.

In cases where municipal and industrial waste treatment utilizes biological processes, pH must be controlled within a range favorable to the particular biological organisms involved. In addition, chemical processes used to coagulate municipal or industrial wastes, dewater sludge, or oxidize certain substances require that the pH be controlled within very narrow limits. The normal pH range of domestic sewage varies from 7.3 to 7.8, which is slightly alkaline. If the pH is significantly below 7.0, the sewage may corrode unprotected metal and concrete and usually indicates that industrial wastes in significant amounts are being discharged to the municipal sewer system without adequate pretreatment.

Chlorides

Chlorides are present in practically all surface water and groundwater, since the chlorides of calcium, magnesium, potassium, and sodium are readily soluble in water. The source can be the natural environment, specifically the leaching of minerals by groundwater movement and surface runoff, or induced through human activities including domestic and industrial waste discharges, agricultural drainage, and urban runoff containing, for example, salts applied to roads for winter maintenance.

During that period of time when streamflow is sustained exclusively by discharge from the groundwater reservoir, the prevailing chloride concentration is usually referred to as the background concentration. This background concentration of chloride in the headwater streams of the Menomonee River watershed ranges from 20 to 50 mg/l. Occasional or persistent concentrations higher than the background chloride concentration indicate the influence of human activities on water quality, and thus chloride data provide a means of detecting possible pollution of surface waters.

Chlorides in surface waters are not generally harmful to humans unless high concentrations—in excess of 1,000 mg/l—are reached. Concentrations of 250 to 400 mg/l, however, impart a salty taste to water, render it unsuitable for many industrial uses, and inhibit growth of certain aquatic plants. Certain industrial uses may be affected by chloride concentrations as low as 30 mg/l.

Dissolved Oxygen

The dissolved oxygen (DO) concentration is often considered to be the single most important indicator of surface water quality. Low dissolved oxygen concentrations in surface waters create an unsuitable environment for fish and other desirable forms of aquatic life, and the absence of dissolved oxygen leads to a septic condition with its associated foul odors and unpleasant appearance.

Major sources of dissolved oxygen in surface waters are the atmosphere and aquatic plant life. Large reductions in dissolved oxygen content are caused by bacteria utilizing oxygen in the process of decomposing carbonaceous and nitrogenous compounds, thereby converting them to simpler, more stable inorganic compounds. In addition, algae and other aquatic plants may cause large daily fluctuations in the dissolved oxygen concentrations of surface waters, as these plants produce oxygen through photosynthesis during the daylight hours and consume oxygen by respiration at night. Such diurnal—daily—dissolved oxygen variations often produce unfavorable effects on desirable forms of aquatic animal life, especially during the low phase of the daily cycle.

Oxygen solubility is temperature-dependent, varying inversely with the water temperature. The highest saturation level at atmospheric pressure is 14.6 milligrams per liter which occurs at 32°F (0°C). The saturation concentration decreases to 8.4 mg/l at 77°F (25°C)—representative of summer streamflow conditions—and to even lower levels at still higher temperatures.

The minimum dissolved oxygen concentration that should be maintained in a stream is dependent upon the desired uses of the stream. In order to prevent the development of anaerobic conditions in a stream, a dissolved oxygen concentration of at least 1.0 mg/l should be maintained. For a stream to support a varied and healthy fishery, Wisconsin Department of Natural Resources water quality standards require a dissolved oxygen concentration of 5.0 mg/l or more.

It is possible for dissolved oxygen levels in surface waters to exceed the saturation concentration—a condition referred to as supersaturation. This condition occurs when the rate of photosynthetic oxygen production temporarily exceeds the rate at which oxygen is either consumed by biochemical processes in the water or diffused into the atmosphere. Supersaturation is, however, a transient condition that does not occur with regularity and, therefore, the incremental oxygen represented by possible occasional supersaturated conditions should not be considered in evaluating the waste assimilative capacity of a stream, lake, or impoundment.

Carbonaceous and Nitrogenous
Biochemical Oxygen Demand

Biodegradation of Organic Substances: Untreated sanitary sewage, biologically treated sanitary sewage, and the treated sewage-receiving water mixture normally contain organic material, that is, compounds containing carbon in combination with one or more elements. This organic material, which is discharged primarily by human beings into sanitary sewerage systems in the form of unused food and discarded body cells, consists primarily of carbohydrates, fats, and proteins.

These organic materials—waste products from man's perspective—constitute food for bacteria. Utilizing a process called biodegradation, or oxidation, these biological agents degrade, or oxidize, the organic material so as to both derive energy and to replace cell structure. Under aerobic conditions, these bacteria utilize free oxygen with the end products of the biodegradation consisting of carbon dioxide and water produced as a result of the oxidation of carbon to obtain energy, simpler and stabler inorganic end products, and residual organic matter having a lower energy content.

The bacterial conversion of most of the potentially noxious and troublesome organic materials to innocuous substances under controlled aerobic conditions is one of the primary functions of a conventional secondary municipal sewage treatment plant employing biological processes. It should be emphasized, however, that the control and treatment of sanitary sewage must, in many cases, include measures in addition to secondary treatment because the biodegradation occurring in that treatment does not eliminate all organic material, thereby resulting in the possibility of continuing adverse biodegradation occurring in the receiving waters. Furthermore, the stable compounds produced as a result of secondary treatment contain nutrients that may, in the absence of advanced treatment intended to remove such nutrients, produce troublesome growths of algae fungi and other aquatic plants in the receiving surface waters.

Certain critical differences occur in the biodegradation of organic substances depending on the nature of the medium. More particularly, and as discussed below, biodegradation of untreated sanitary sewage as normally received at a municipal sewage treatment plant may be distinctly different in sewage treatment plant operation from the biodegradation process occurring in both the treated sewage discharged from that plant and in the mixture of that treated sewage and the receiving waters.

CBOD and NBOD in Untreated Sewage: In untreated sanitary sewage, composed primarily of domestic wastewater, the process whereby bacteria utilize oxygen and convert some of the organic matter to stable compounds is normally divided into two distinct stages: a first stage lasting 5 to 15 days during which bacteria biodegrade or oxidize carbonaceous substances, and a second stage—nitrification—that is evident in receiving streams and during which nitrifying bacteria oxidize ammonia to nitrites and then nitrates.

For the purpose of this report, carbonaceous biochemical oxygen demand (CBOD) is used as a measure of the oxygen required to complete the first stage of the oxidation process. It does not include the additional oxygen required during the second, or nitrification, stage to oxidize ammonia. The later oxygen demand is treated separately and quantified using the concept of nitrogenous biochemical oxygen demand (NBOD). The 5- to 15-day lag in the initiation of the NBOD process relative to the CBOD process is attributable to the relatively small population of bacteria in untreated sewage that is capable of oxidizing nitrogenous compounds. Figure 57 illustrates CBOD and NBOD exertion as a function of time as these processes typically occur in untreated sanitary sewage. In particular, Figure 57 depicts initiation of the NBOD process well after the initial appearance of the CBOD process—about 10 days—and also demonstrates how the rates of exertion of both CBOD and NBOD eventually decrease and asympotically approach ultimate values.

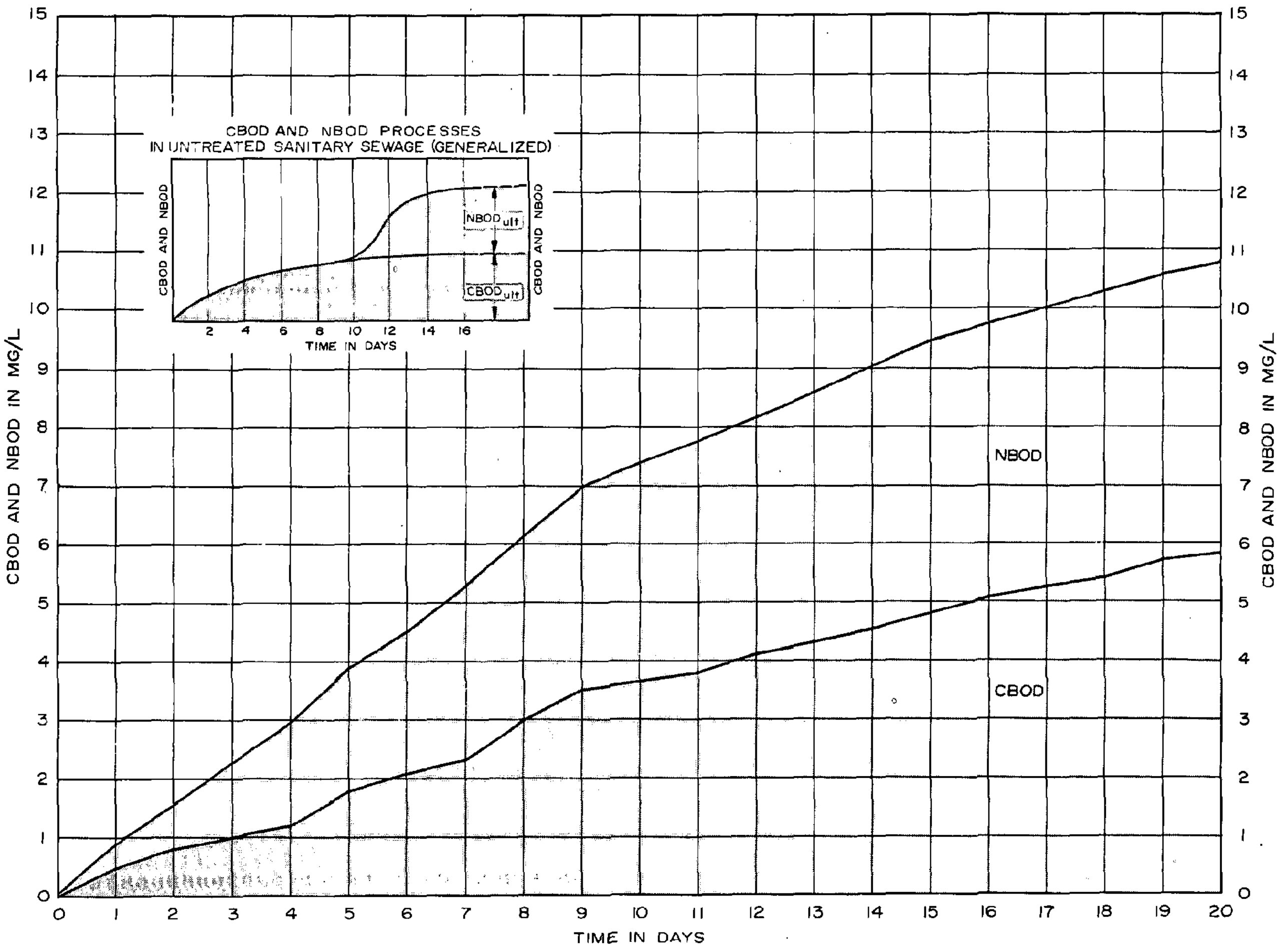
The ultimate carbonaceous biochemical oxygen demand ($CBOD_{ult}$) of untreated sanitary sewage is, for the purpose of this report, defined as the quantity of oxygen required by bacteria under aerobic conditions to degrade the carbonaceous organic material to carbon dioxide and water. Similarly, the ultimate nitrogenous oxygen demand ($NBOD_{ult}$) is, for the purpose of this report, defined as the quantity of oxygen required by bacteria under aerobic conditions to oxidize ammonia to nitrates (NO_3) and water. The magnitude of both the $CBOD_{ult}$ and $NBOD_{ult}$ is important to water quality planning, since the removal of varying proportions of each of these demands in the influent sewage may be necessary and should be considered to meet established water use objectives.

Although laboratory tests are available for determining the $CBOD_{ult}$ and the $NBOD_{ult}$ of a sanitary sewage sample, these tests are not commonly used in connection with sewage treatment plant management because of the long time required to conduct the tests. In the operation of such a facility, for example, influent and effluent $CBOD_{ult}$ determination made for the purpose of adjusting the plant operation so as to optimize the treatment efficiency must be completed within a period approximating that over which major changes in hydraulic loads or sewage quality may occur. That time period would typically be on the order of several days rather than several months.

Consequently, a five-day carbonaceous biochemical oxygen demand test conducted at 20°C (68°F) has been developed, standardized, and adopted by engineers to provide a practical indicator of the oxygen demand of sanitary sewage, or of at least of the carbonaceous component of the ultimate biochemical oxygen demand normally satisfied in a secondary sewage treatment plant. The five-day, 20°C CBOD test ($CBOD_5$) is defined as the amount of dissolved oxygen used by aerobic

Figure 57

CARBONACEOUS AND NITROGENOUS BIOCHEMICAL OXYGEN DEMAND
IN UNTREATED SANITARY SEWAGE AND IN RECEIVING WATERS



Source: Wisconsin Department of Natural Resources and SEWRPC.

bacteria to biodegrade or oxidize carbonaceous organic material during a five-day period at a temperature of 20°C expressed in milligrams per liter (mg/l) of dissolved oxygen or in pounds of dissolved oxygen for a given quantity of sanitary sewage. A typical value of $CBOD_5$ for domestic wastewater is 200 mg/l. If, for example, the average daily sewage flow were one million gallons, the $CBOD_5$ of 200 mg/l would be equivalent to, and could be expressed as, 1,668 pounds of $CBOD_5$ per day.

The five-day period required for the standard $CBOD_5$ test is short enough to facilitate practical application of the test results in general water quality management, and sewage treatment plant operation in particular. Laboratory experience indicates that the five-day test is relatively reliable in that there is low scatter of test data at five days. The five-day period is advantageous in that it is prior to the onset of the NBOD process in untreated sanitary sewage and therefore may be expected to reflect only the CBOD processes, even if steps are not taken to inhibit the NBOD process. A temperature standard is necessary if test results are to be comparable because the rate of oxygen utilization during the first five days of CBOD exertion is markedly dependent on temperature.

Based on theoretical analyses of the CBOD process and laboratory studies on the process, an equation has been derived for the purpose of computing $CBOD_{ult}$ as a function of $CBOD_5$ and a constant—the CBOD deoxygenation rate constant.[4] For example, a $CBOD_5$ value of 200 mg/l and a laboratory condition CBOD process deoxygenation rate constant of 0.30 per day (base e computations) would

[4] $CBOD_{ult} = CBOD_5/(1\text{-}e^{-5k})$ *where k is the deoxygenation rate constant in units of 1/day.*

yield, using the aforementioned equation, a $CBOD_{ult}$ of 258 mg/l. Using the same value of the deoxygenation rate constant, each pound of $CBOD_5$ entering the sewage treatment plant would require 1.29 pounds of oxygen for complete degradation of the carbonaceous organic material.

CBOD and NBOD in Treated Sewage and in the Treated Sewage-Receiving Water Mixture: In sewage subjected to conventional secondary treatment and in mixtures of such treated sewage and receiving waters, the CBOD process and the NBOD process may be expected to occur simultaneously, or the initiation of NBOD may lag slightly by a few days as illustrated in Figure 57. That is, the 5- to 15-day lag of the NBOD process behind the CBOD process, as exhibited in the case of untreated sanitary sewage, is not expected in either biologically treated sanitary sewage or in the receiving waters downstream of the point at which the treatment plant discharge enters the stream.

This conclusion is supported by field data in the sense that, in those river reaches receiving effluent from biological treatment plants where instream nitrification has been demonstrated or deduced, the NBOD and CBOD processes were observed to occur simultaneously or the NBOD process began within a few days of the initiation of CBOD. Furthermore, these studies have concluded that the NBOD process as well as the CBOD process may be important and should be taken into account in streams receiving discharges from biological treatment plants.[5,6,7,8,9]

Several explanations are given for the distinctly different CBOD and NBOD processes in untreated sanitary sewage relative to the CBOD and NBOD process in biologically treated sewage or in the mixture of treated sewage and the receiving waters. After secondary treatment, not only are there more nitrifying bacteria present, but the biological treatment process will partially decompose some of the complex organic nitrogen forms into the simpler form of ammonia nitrogen, thereby providing a large supply of ammonia in the effluent to be oxidized in the flowing stream. Secondary sewage treatment plant effluent contains 10 to 20 mg/l ammonia nitrogen where "ammonia nitrogen" is defined as ammonia, NH_3, expressed as nitrogen, N. If one assumes that all of this will be oxidized to nitrate, a considerable oxygen demand will be imposed on the receiving stream, since 4.6 pounds of oxygen are required to oxidize one pound of ammonia nitrogen. In the summer, a well-developed population of nitrogen-oxidizing bacteria often exists in the stream immediately downstream of an effluent discharge point, and ammonia in the effluent may, under these conditions, result in the exertion of a heavy, immediate oxygen demand on the receiving stream waters, reducing dissolved oxygen levels below these required to sustain aquatic life and meet water use objectives.

It should be noted that high ammonia levels in secondary sewage treatment plant effluents are an important consideration in water quality management, not only because of the potential for generating instream nitrification and commensurate oxygen depletion, but also because of the potential toxic effect of high instream ammonia concentrations on fish life. The allowable ammonia concentration increases with increasing alkalinity due to the buffering properties of calcium carbonate, but decreases with increasing pH[10,11,12] and decreases with increasing temperature.[13] For purposes of this report, and in light of the alkalinity and pH levels common to the watershed's surface waters, ammonia was assumed to be potentially toxic under summer conditions in concentrations in excess of 2.5 mg/l expressed as ammonia nitrogen.

The five-day, 20°C carbonaceous biochemical oxygen demand ($CBOD_5$), the ultimate carbonaceous oxygen demand ($CBOD_{ult}$), and the ultimate nitrogenous biochemical oxygen demand ($NBOD_{ult}$) of treated sanitary sewage or of surface waters receiving treated sanitary sewage are all defined as above for untreated sewage. And, as was the case for untreated sewage, only the $CBOD_5$ test is routinely made on effluent samples or stream samples, with the results mathematically extrapolated to estimate $CBOD_{ult}$. Procedures, however, are available for determination of $NBOD_{ult}$, one of these

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[5] *R. L. O'Connell and N. A. Thomas, "Effect of Benthic Algae on Stream Dissolved Oxygen," Journal of the Sanitary Engineering Division, ASCE, June 1965.*

[6] *C. T. Wezernak and J. J. Gannon, "Evaluation of Nitrification in Streams," Journal of the Sanitary Engineering Division, ASCE, October 1968.*

[7] *W. Whipple, et al, "Dissolved Oxygen Dynamics and Analytic Procedures," Instream Aeration of Polluted Rivers, Chapter III, Water Resources Research Institute, Rutgers University, August 1969.*

[8] *D. J. O'Connor and D. M. DiToro, "Photosynthesis and Oxygen Balance in Streams," Journal of the Sanitary Engineering Division, ASCE, April 1970.*

[9] *R. C. Mt. Pleasant and W. Schlickenrieder, "Implications of Nitrogenous BOD in Treatment Plant Design," Journal of the Sanitary Engineering Division, ASCE, October 1971.*

[10] *Water Quality Critiera, Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, Washington, D. C., April 1968. Reprinted by the U. S. Environmental Protection Agency, 1972.*

[11] *G. E. Hutchinson, A Treatise on Limnology, Vol. I, Wiley, New York, 1957, p. 850.*

[12] *Mt. Pleasant and Schlickenrieder, op. cit.*

[13] *Letter to SEWRPC from Jerome R. McKersie, Chief, Water Quality Evaluation Section, Wisconsin Department of Natural Resources, November 7, 1975.*

procedures consists of parallel continuous analyses of the CBOD process and the NBOD process on a divided sample. Such analyses, which last for a period in excess of 10 to 20 days depending on the observed behavior of the particular samples, discriminate between the CBOD process and the NBOD process, suppressing the occurrence of the latter in one of the two analyses.[14]

The $CBOD_{ult}$ and $NBOD_{ult}$ of a sewage treatment plant effluent are a primary determinant of the potential decrease in dissolved oxygen concentrations that will result if that wastewater is discharged into a stream. The actual decrease in dissolved oxygen downstream of the wastewater discharge is dependent upon many factors, including the ratio of streamflow to effluent discharge, the $CBOD_{ult}$ and $NBOD_{ult}$ of the effluent, the $CBOD_{ult}$ and $NBOD_{ult}$ of the stream, the rate at which the CBOD and NBOD processes occur, and the dissolved oxygen content and reaeration characteristics of the wastewater-stream mixture. A knowledge of these factors is important in water quality studies in order to determine whether a waste discharge will deplete surface water oxygen levels to such an extent that the suitability of the water for certain uses will be impaired.

Factors Influencing the Nitrification Process in Streams:[15]
Numerous factors determine both the occurrence of nitrification in flowing streams receiving discharges from municipal sewage treatment plants and the rate and manner in which that nitrification proceeds. Even though there are many potential nitrification-suppressing factors that could occur in the watershed, it is likely that instream nitrification will occur with sufficient severity in stream reaches downstream of secondary sewage treatment plants to merit consideration of the phenomenon in water quality management.

Dissolved oxygen levels below approximately 1.5 mg/l suppress instream nitrification. This concentration is well below the minimum required for the maintenance of a fishery and, if that use is to be achieved, instream oxygen levels may be expected to be favorable for nitrification.

Water temperatures below about $50^{o}F$ may be expected to inhibit instream nitrification. Water quality conditions are often critical during summer low-flow periods during which stream temperatures are well above the aforementioned lower limit of $50^{o}F$ and are, therefore, favorable for the occurrence of nitrification.

Instream nitrification is affected by pH, with the optimum range appearing to be between about 7.0 and 9.0, a pH range that is very likely to exist throughout most of the Menomonee River watershed. Free bicarbonate ions or carbon dioxide are required by nitrifying bacteria as the source of carbon for new cell growth. In the Menomonee River watershed, these substances may be expected to be generally available in concentrations exceeding that required by the nitrifying bacteria.

Under conditions of high organic carbon content, carbon oxidizing bacteria may predominate over nitrogen oxidizing bacteria, thus inhibiting the activity of the latter and thereby suppressing nitrification. While this condition would be expected in untreated sewage or streams subjected to a high degree of organic pollution, it would not be expected in surface waters, like those in the Menomonee River watershed, receiving discharges from municipal sewage treatment plants providing at least secondary treatment. If sufficient quantities of phytoplankton are present, they may utilize ammonia directly as a nutrient source, thereby possibly inhibiting nitrification, that is, the oxidation of ammonia nitrogen to nitrates.

Coliform Bacteria
The number of coliform bacteria in water is the most widely used indicator of the possible presence of disease-producing organisms. Coliform bacteria are easily detected and apparently harmless microorganisms which occur in extremely large concentrations in the intestinal tracts of man and warm-blooded animals, along with pathogenic—disease-producing—bacteria. Therefore, the presence of large numbers of coliform bacteria in a water is used as an indicator of the possible presence of enteric pathogens in that water, while the absence of coliform bacteria is used as an indicator of the probable absence of pathogenic bacteria. Coliform bacteria are also present in the soil, however, and therefore may originate from sources other than the human intestinal tract, so that a high coliform count is not necessarily indicative of fecal pollution. Tests have been developed to determine the number of actual fecal coliform organisms present in water, and such tests are considered a better indicator of the probable presence of disease-producing organisms than total coliform tests. Inasmuch as fecal coliform counts have only recently come into widespread use in routine sampling and analysis programs, the interpretation of historic data is complicated by the presence of the two forms of data: fecal coliform and total coliform. A high degree of correlation has been established between high coliform counts in drinking water and epidemics of water-borne diseases such as typhoid, but in waters used for recreational purposes, the correlation between high coliform counts and disease has not been so well established.

The drinking water standards established in 1974 by the Wisconsin Department of Natural Resources limit the mean total coliform concentration in treated drinking water to one colony per 100 ml by the membrane filter coliform count (MFCC) method. In water used for recreational purposes, State of Wisconsin standards specify a monthly geometric mean membrane filter fecal coliform count (MFFCC) based on a minimum of five samples per month of not more than 200 colonies per 100 ml, and a maximum count not exceeding 400 colonies per 100 ml for more than 10 percent of the samples during any month.

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[14] *W. Whipple et al, op cit.*

[15] *See the following for a literature review of factors reviewing instream nitrification: Addendum to Simplified Mathematical Modeling of Water Quality, prepared by Hydroscience, Inc., for the U. S. Environmental Protection Agency, Washington, D. C., May 1972.*

Nutrients

Nutrients may be defined as those chemical elements necessary for the growth of plant life. While a certain amount of nutrients is desirable to produce a balanced aquatic flora and fauna, excessive fertilization produces large growths of algae, aquatic plants, and organisms which inhibit desirable forms of aquatic life including fish, that limit recreational activities, and create an aesthetic nuisance. Such nuisances include unsightly algae accumulations and masses of floating aquatic plants and the noxious conditions—primarily odor—associated with massive, rapid die-offs of algae and aquatic plants.

Many different nutrients are essential to plant growth. Some, termed micronutrients, may be present in only very small or trace quantities. These include iron, manganese, copper, zinc, molybdenum, vanadium, chlorine, boron, cobalt, and silicon. Others, termed macronutrients, must be present in large amounts and include phosphorus, nitrogen, carbon, hydrogen, oxygen, potassium, magnesium, calcium, and sulphur.

The nutrients most often cited as causing problems of overfertilization in surface waters are nitrogen and phosphorus. Studies[16] have indicated that the approximate threshold concentrations for algae growth in lakes are 0.1 mg/l nitrate-nitrogen and 0.01 mg/l phosphate-phosphorus. Generally, algae growth in the presence of 0.1 mg/l or more of nitrate-nitrogen is inhibited when the phosphate-phosphorus concentrations are less than 0.01 mg/l. Nitrate-nitrogen concentrations below 0.1 mg/l, however, can be supplemented by nitrogen-fixation which occurs in the blue-green algae.[17,18] Therefore, nuisance algae blooms may occur in lakes when the phosphate-phosphorus levels exceed the threshold concentration and the nitrate-nitrogen levels remain below 0.1 mg/l. Blooms by non-nitrogen fixing algae can be anticipated when the average phosphate-phosphorus concentrations equal or exceed 0.01 mg/l and the inorganic nitrogen[19] concentrations exceed 0.3 mg/l.[20] In addition to nitrogen and phosphorus, algae and other aquatic plants depend on the presence of other macronutrients, such as carbon and silicon, and micronutrients, which include vitamins and other trace elements for growth. Therefore, nuisance growths of aquatic plants require adequate concentrations of other elements, as well as appropriate physical conditions, such as temperature, light, suitable substrates in the case of rooted aquatic plants, and depth. In lakes that stratify a measurable increase in the nutrient phosphorus content may occur in the hypoliminion, and phosphorus may be brought to the surface during the spring and fall turnovers of the lake, thereby resulting in spring and autumnal algae blooms. Federal reports on water quality criteria,[21,22] contain guideline values of a maximum of 0.10 mg/l total phosphorus in flowing streams and 0.05 mg/l in streams entering lakes or reservoirs to prevent nuisance growth of aquatic plants in streams and lakes. Similar criteria for nitrogen levels in streams are not available.

With respect to controlling algae and aquatic plant growths in surface waters by limiting the influx of a critical nutrient, contemporary water management practice is to place emphasis on phosphorus control rather than on the control of nitrogen or other necessary nutrients and elements. The most important sources of phosphorus are municipal sewage treatment plant effluent and runoff from rural and urban land surfaces, each of which is subject to a substantial degree of control. That is, the quantity, timing, and entry point of most of the phosphorus entering the surface water system is subject to management. In contrast, a large quantity of nitrogen is present in the atmosphere and can be removed from that reservoir by rainfall and by nitrogen-fixing algae—processes that are not subject to control.

Aquatic Flora and Fauna

A biological assay which includes a qualitative and quantitative examination of the types of organisms represented and their population density in a river, stream, lake, or impoundment provides a good indication of the prevailing level of the water quality since it reflects, both directly and indirectly, the chemical and physical properties within that particular environment, the extent and degree of pollution, the degree of self-purification, and the water use potential.

As a rule, unpolluted waters usually support a large number of different species with relatively few individuals representing a particular species. In contrast, surface waters subjected to excessive loads of oxygen-demanding substances and nutrients usually are characterized by large populations of relatively few species of the more pollution-tolerant forms. Therefore, the degree of pollution may be measured by the number of individual organisms per number of species per unit area or volume, depending on the habitat in question.

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[16] *State of California Publication No. 34, Eutrophication—A Review, State Water Quality Control Board, 1967, p. 30.*

[17] *P. Fay et al, "Is the Heterocyst the Site of Nitrogen-Fixation in Blue-green Algae?" Nature 220:810, 1968.*

[18] *W. G. W. Kurz and T. A. LaRue, "Nitrogenase in Anabaera flos-aquae Filaments Lacking Heterocysts," Naturwissenschatten 58:417, 1971.*

[19] *Inorganic nitrogen includes the nitrate-nitrogen, nitrite-nitrogen and ammonia-nitrogen concentrations collectively.*

[20] *C. N. Sawyer, "Fertilization of Lakes by Agricultural and Urban Drainage," Journal New England Water Works Association, vol. 61, 1947.*

[21] *Water Quality Criteria, Report of the National Technical Advisory Committee, p. 34.*

[22] *Water Quality Criteria, Ecological Research Series, U. S. Environmental Protection Agency, March 1973, p. 81.*

Floral types commonly found in the Menomonee River and its tributaries, especially in the clean headwater reaches, might include the more intolerant forms of algae such as Cladophora and Cyclotella. In the reaches of recovery or deteriorating water quality conditions, the more facultative algae forms—those able to exist under widely varying conditions, such as Spirogyra and Navicula—commonly are found. And in those stream reaches undergoing active decomposition of organic sediments, such as found within the combined sewer service areas, populations of the very tolerant forms of algae such as Oscillatoria and Chlamydomonas usually are more common.

Some characteristic types of fauna found in the Menomonee River and its tributaries might include pollution-intolerant populations of Stenonema, a mayfly nymph, and Trichoptera, caddisfly larva, in the clean headwater reaches. Intolerant fish populations including the Daces and Stonerollers usually inhabit these reaches. The stream reaches of deteriorating or recovering water quality conditions typically contain populations of the more facultative forms. Benthic organisms including Chironomid larva (midges) and Asellus (sowbugs) and fishes including brook sticklebacks and creek chubs inhabit these reaches. The stream reaches of active decomposition, again as found in the combined sewer service areas, maintain benthic organism population considered to be very tolerant to pollution, such as the Tubificidae (sludgeworms) and Pisidium (a fresh water clam). The fish populations often found in these zones include carp and black bullheads.

Heavy Metals

Heavy metals such as cadmium, chromium, cobalt, copper, lead, mercury, nickel, and zinc are those which have a specific gravity greater than four, have several oxidation states, and readily form complex ions. Heavy metals may enter the surface water system as a result of discharges from industrial processes such as electroplating or as washoff from urban and agricultural lands. The heavy metals that accumulate on or beneath the land surface between runoff events may be traced to a variety of sources such as motor vehicle exhaust, atmospheric fallout and washout, pesticide application, solid waste disposal site leachate, and gradual wear and disintegration of motor vehicle brake linings, tires, and other parts. Certain heavy metals, such as copper in the form of copper sulfate, are intentionally added to surface waters to control algae and snails that carry swimmers itch.

The effects of the heavy metals in the aquatic system vary greatly and are often dependent on such factors as concentration, hardness, pH, and temperature of the receiving waters, and the presence of other compounds with which the heavy metals may react. Concentrations which are toxic to many forms of aquatic life may not be harmful to man. A particularly troublesome aspect of heavy metals, however, is that they tend to accumulate in the tissues of living organisms with the concentration increasing up the food chain so as to present a potential threat to the human population. There are reported instances of people being poisoned by eating fish that had accumulated large concentrations of the heavy metal mercury in their flesh as a result of ingesting lower aquatic forms which had assimilated the mercury directly from the water.[23]

The specific effects of heavy metals on man and other forms of life are many and varied. For example, excessive concentrations of cadmium are associated with liver and kidney disorders in man, and are toxic to fish and their food sources. Chromium may be toxic to man and is also a possible carcinogen, in addition to being toxic to fish and aquatic life. Although trace amounts of copper are essential to man, large quantities may cause liver damage. Lead and mercury are toxic to humans as well as to fish and other aquatic life.[24]

Only within the past decade have heavy metals become a matter of widespread concern as examples of fish contamination became known, followed by improved laboratory analysis techniques. While existing technology such as activated carbon and chemical precipitation processes can be employed to remove heavy metals at industrial and municipal wastewater treatment facilities, the ultimate control of heavy metals is contingent upon first determining the location, characteristics, and relative importance of the many and varied diffuse sources in a watershed and then devising appropriate control measures.

Organic Pesticides

Organic pesticides are chemicals that are utilized by man to control or destroy undesirable forms of plant and animal life. Pesticides encompass all forms of insecticides, herbicides, fungicides, fumigants, nematocides, algacides, and rodenticides.

Pesticides and their residues may enter the surface waters via surface and ground water runoff from both urban and rural land uses. Some pesticides, such as herbicides used for aquatic weed control, are applied directly to the surface waters. Pesticides, like heavy metals, accumulate in the tissues of living organisms with the concentration increasing up the food chain and thus presenting a potential threat to the human population.

Pesticides can be generally classified into four groups: chlorinated hydrocarbons, organophosphorus insecticides, carbamate insecticides, and chlorophenoxy herbicides. The chlorinated hydrocarbons, which include DDT, aldrin, dieldrin, chlordane, heptachlor, and lindane, are synthetic organic insecticides that are very stable in the environment in that they are not easily broken down in the bodies of man or animals. These poisons affect the

[23] *Water Quality Criteria—1972, Ecological Research Series, U. S. Environmental Protection Agency, March 1973, p. 251.*

[24] *Water Quality Criteria—1972. Note that cadmium is discussed on p. 60 and pp. 179-180, chromium on pp. 62 and 180, copper on p. 64, lead on p. 70 and p. 181, and mercury on p. 72, 181, and 251.*

nervous system, particularly the brain, and in very severe poisonings may cause death. The organophosphorus insecticides, which include approximately 30 types of which parathion is potentially the most dangerous to man, are synthetic organic compounds that may affect the nervous system in man by inhibiting certain enzymatic reactions necessary for proper neural functions. The carbamate insecticides such as Aminocarb, Bayer, Baygon, Carboryl, and Zectian are very similar to the organophosphorus insecticides in their toxic mechanisms. The chlorophenoxy herbicides have been widely used to control both aquatic and terrestrial vegetation. Experiments have generally indicated ambiguous toxic effects in man from chlorophenoxy herbicides.[25]

Concentrations of pesticides and pesticide residues, particularly those which are not soluble in water, can be reduced by sewage treatment facilities. However, care is needed to assure that concentrations of pesticides do not reach levels which would be toxic to the organisms necessary for the biological processes involved in the sewage treatment. The best methods to reduce pesticides in surface waters are to reduce the amount of pesticide applied to an area, to use pesticides that are more target-specific—that is, destroy only those forms of life for which they are intended—and to use pesticides that are completely biodegradable.

Iron and Manganese

Iron and manganese are dissolved from nearly all rock and soil, and objectionable amounts occur in most groundwaters in the watershed. Many uses of water are adversely affected by high iron and manganese content. Concentrations of iron higher than about 0.3 mg/l and manganese higher than about 0.05 mg/l stain laundry, porcelain, and enamelware. Iron and manganese in water supplies are objectionable for food processing, beverage manufacturing, dyeing, bleaching, ice manufacturing, and brewing. High iron and manganese concentrations cause an unpleasant, bitter taste. When exposed to air for even a short time, iron and manganese in groundwater tend to oxidize and form, respectively, objectionable reddish-brown and black precipitates.

Sodium

Sodium is a common element contained in nearly all soil and rock, and, because most sodium salts are very soluble, all groundwater normally will contain sodium. Sodium also may enter the groundwater system through industrial and municipal waste discharges containing sodium compounds. No recommended limiting or maximum permissible concentration of sodium is established in the Wisconsin Department of Natural Resources drinking water standards. Persons with heart, kidney, or circulatory diseases, however, require drinking and culinary water that contains little or no sodium. More than 50 mg/l sodium and potassium in the presence of suspended matter causes foaming, which in turn accelerates scale formation and corrosion in boilers. Sodium and potassium carbonate in circulating cooling water can cause deterioration of wood in cooling towers, and more than 65 mg/l of sodium can cause problems in ice manufacturing. Irrigation water high in sodium content may be toxic to plants and adversely affect soil conditions.

Bicarbonate, Carbonate, and Alkalinity

Bicarbonate and carbonate anions in groundwater are primarily the result of the interaction of carbon dioxide and water with calcium and magnesium carbonate rocks (limestone and dolomite). Carbonate salts, however, are generally insoluble, and therefore, are seldom present in groundwater.

Bicarbonate anions are present in all aquifers in the watershed in concentrations that may limit water use. The presence of the bicarbonate anion in water produces alkalinity, which increases the corrosiveness of water. Bicarbonates of calcium and magnesium decompose in steam boilers and hot water facilities to form carbonate scale and release corrosive carbon dioxide. Bicarbonate concentrations in water have little public health significance. If present in large quantities, however, taste is affected. Alkalinity is a property of water rather than a specific constituent. This property involves the ability of water to neutralize acid and is due to the presence of bicarbonate, carbonate, and hydroxide anions. Total alkalinity is the sum of the above three anions expressed as $CaCO_3$.

Calcium, Magnesium, and Hardness

Calcium and magnesium are contained in relatively large concentrations in the aquifers of the watershed, being dissolved from limestone, dolomite, and other rock and soil. High calcium and magnesium concentrations in the groundwater are the major causes of hardness and scale-forming properties. Groundwater containing small concentrations of dissolved calcium and magnesium, however, is preferable for certain industrial processes, including electroplating, tanning, dyeing, and textile manufacturing.

Hardness is the sum of calcium and magnesium concentrations expressed as $CaCO_3$ and is a property of water rather than a constituent. This property is commonly related to the use of soap and the formation of boiler scale. Water is considered to be "hard" when sodium or potassium stearate soaps form little suds and lots of insoluble curd, which floats upon the water and adheres to sinks and tubs, or when water, upon being heated, forms scales or deposits in boilers, hot water heaters, and in pipes, or on the cooking surfaces of pots. "Soft" water reacts with soap to form much suds and little or no curd. Upon heating, "soft" water does not tend to develop scale.

Sulfate

Sulfate concentrations in groundwater result primarily from the leaching and oxidation of sulfide and sulfate minerals contained in the soil and rock of the watershed. Sulfate may also enter the groundwater system through the percolation of waste discharges from industries that

[25] *Water Quality Criteria—1972, Ecological Research Series, U. S. Environmental Protection Agency, March 1973.*

use sulfates or sulfuric acid or that produce sulfates in their manufacturing processes. Sulfate is also contributed from atmospheric sources through precipitation. Concentrations greater than 250 mg/l exceed the recommended limiting sulfate concentrations for drinking water, imparting a taste to water. Sulfate acts as a laxative at concentrations greater than 750 mg/l.

Fluoride

Fluoride compounds are not naturally abundant and occur in relatively small quantities within the watershed. The presence of fluoride in drinking water may be either beneficial or harmful, depending upon its concentration and water consumption. Fluoride in drinking water reduces tooth decay when the water is consumed during the period of enamel calcification. Fluoride may, however, cause mottling of the teeth, depending upon the concentration of the fluoride, the amount of the drinking water consumed, and the age and susceptibility of the individual. The concentration of fluoride recommended varies with the annual average maximum daily air temperature.

Nitrate and Nitrite

Nitrate in groundwater is the result of decaying organic matter, nitrate compounds in soil, domestic and municipal sewage, fertilizer, or waste discharges of food and milk processing industries. Nitrate is also contributed from atmospheric sources through precipitation. As might be expected, shallow wells and springs are more likely to produce water with high nitrate content than are deep wells, due to the relative ease with which the shallow aquifers are recharged with surface water. Drinking water standards established by the Wisconsin Department of Natural Resources recommend that the nitrate content (as NO_3) not exceed 45 mg/l. There is evidence that higher concentrations may cause a blood disorder in infants called methemoglobinemia (blue babies). Nitrate in water in concentrations much greater than the local average may suggest contamination by sewage or other organic matter. In concentrations less than 10 mg/l, nitrate has no adverse effect on most water uses.

Nitrite in groundwater is produced by bacteria from soil ammonia. Nitrite is unstable in the presence of oxygen and is present in only minute quantities in most natural waters. The presence of nitrite in water sometimes indicates organic pollution. Nitrite is toxic but rarely occurs in large enough concentrations to cause a health hazard.

WATER USE OBJECTIVES AND SUPPORTING WATER QUALITY STANDARDS

The water use objectives and supporting standards adopted by the Wisconsin Department of Natural Resources and applicable to the Menomonee River watershed are discussed in detail in Chapter X of this volume. As indicated in Chapter II of Volume 2 of this report, these state-adopted objectives and standards have been recommended for the Menomonee River watershed except that a higher use and a more stringent standard have been recommended for that reach of the main stem of the Menomonee River bounded on the upstream end by the Menomonee River-Honey Creek confluence and on the downstream end by Hawley Road.

The state-adopted use objectives for the surface waters of the watershed are shown on Map 82 and the supporting standards are set forth in Table 96. In addition to the requirement that all the surface waters satisfy minimum standards, most of the stream system is designated for recreational use and fish and aquatic life. The exceptions are Honey Creek, the South Branch of Underwood Creek, the lower portion of Underwood Creek, and the extreme lower reaches of the Menomonee River, all of which are in the less stringent restricted use category.

The water use objectives and supporting water quality standards are particularly relevant to this chapter since they provide a scale against which the historic and existing water quality of the surface water system of the watershed can be evaluated. For example, the standards specify for all stream flows at or above the 7 day-10 year low flow, a minimum dissolved oxygen level, a pH range and a maximum fecal coliform count for those river reaches designated for recreation and fish and aquatic life uses and for those reaches designated for restricted uses. In addition, by explicit reference to "Water Quality Criteria,"[26] the water use objectives and standards incorporate recommended maximum and minimum levels for many other water quality indicators. The analyses of historic and existing water quality in the Menomonee River watershed were based upon comparisons of water quality data and the adopted water use objectives and supporting standards.

POLLUTION SOURCES

An evaluation of water quality conditions in the Menomonee River watershed must include an identification, characterization, and, where feasible, quantification of known pollution sources. The following types of pollution sources have been identified in the watershed and are discussed below: municipal sewage treatment facilities, sanitary and combined sewerage system overflow points, industrial discharges, urban storm water runoff, and agricultural and other rural runoff. The principal purpose of the chapter is to identify the type and location of the various pollution sources and to quantify the pollutional discharge from those sources in terms of rate or amount of discharge and concentration and total transport of pollutants.

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[26] *Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, April 1968. Reprinted by U. S. Environmental Protection Agency, April 1972.*

Note: The Wisconsin Department of Natural Resources routinely uses the similar but more recent report Water Quality Criteria—1972, Ecological Research Series, U. S. EPA, March 1973, except in those cases where water quality criteria set forth in the 1968 report are more stringent.

Some of the data presented herein are based on surveys conducted 10 to 25 years ago. The principal purpose of summarizing the results of these surveys is to demonstrate that some of the types of pollution problems now evident in the watershed are not of recent origin but have existed for several decades. The conclusions drawn on current water quality conditions, however, are based primarily on data obtained over the past decade.

Water Quality Data

A variety of data sources is available for use in assessing the historic and existing water quality in the Menomonee River watershed. Each of the sources used in the watershed study is cited and briefly described below. The information selected for use from these sources as well as the conclusions drawn from that information are discussed in subsequent sections of this chapter.

Wisconsin Department of Natural Resources Basin Surveys: 1951-1969: The Wisconsin Department of Natural Resources and its predecessor agencies, as part of a statewide water quality monitoring program, have conducted five basin surveys that have included all or part of the Menomonee River and its three principal tributaries, namely, Honey Creek, Underwood Creek, and the Little Menomonee River. The purpose of the surveys was to identify the major point sources of pollution and to determine the effects of these discharges on the quality of receiving waterways. The survey findings are documented in the following reports:

- "Report of Investigations of Pollution of Surface Waters in the Major Portion of the Milwaukee River Basin Conducted During 1951." Wisconsin Division of Water Pollution Control, January 1952. With respect to the Menomonee River watershed, this survey included a very limited amount of water quality sampling along the Menomonee River in Germantown and Menomonee Falls. In addition, benthic—bottom—samples were taken along the main stem within the present Village of Germantown.

- "Report of Investigations of Pollution of Surface Waters in Milwaukee County and that Portion of the Root River System Draining from Waukesha County through Milwaukee County Conducted During 1952 and 1953." Committee on Water Pollution, March 1954. This survey included summer and fall 1952 and 1953 water quality sampling in Milwaukee County on the Menomonee River and four major tributaries: the Little Menomonee River, Butler Ditch, Underwood Creek, and Honey Creek. These water quality data were supplemented with benthic animal samples taken along the Menomonee River, the Little Menomonee River, and Honey Creek.

- "Report on a Field Investigation of Surface Water Quality in Southeastern Wisconsin in the Summer of 1962." Wisconsin Department of Natural Resources (no date). This survey included summer water quality sampling on the Menomonee River above and below the Village of Germantown's Old Village municipal sewage treatment plant and the Village of Menomonee Falls' two sewage treatment plants.

- "Report on an Investigation of the Pollution in the Milwaukee River Basin Made During 1966 and 1967." Wisconsin Department of Natural Resources, January 1968. Menomonee River watershed stream system sampling locations included in this survey were located outside of Milwaukee County along the Menomonee River, Underwood Creek, and Dousman Ditch. Water quality analyses were performed on the three streams while benthic analyses were limited to the Menomonee River.

- "Report on an Investigation of the Pollution of the Milwaukee River, Its Tributaries, and Oak Creek Made During 1968 and 1969." Wisconsin Department of Natural Resources, May 1969. For this survey, water quality sampling locations were established along the length of the Menomonee River within Milwaukee County and at a few locations on the Little Menomonee River, Underwood Creek, and Honey Creek. Benthic organism samples were taken along the Menomonee River and the Little Menomonee River in Milwaukee County.

SEWRPC Water Quality Study: 1964-1965: During a 14-month period extending from January 1964 through February 1965, the Commission conducted an extensive stream water quality sampling program during which almost 4,000 water samples were collected at 87 sampling stations established on 43 streams in the Region. This included samples taken at 12 locations in the Menomonee River watershed. As shown on Map 59, nine of these were located along the length of the Menomonee River while one station each was located on the Little Menomonee River, Underwood Creek, and Honey Creek.

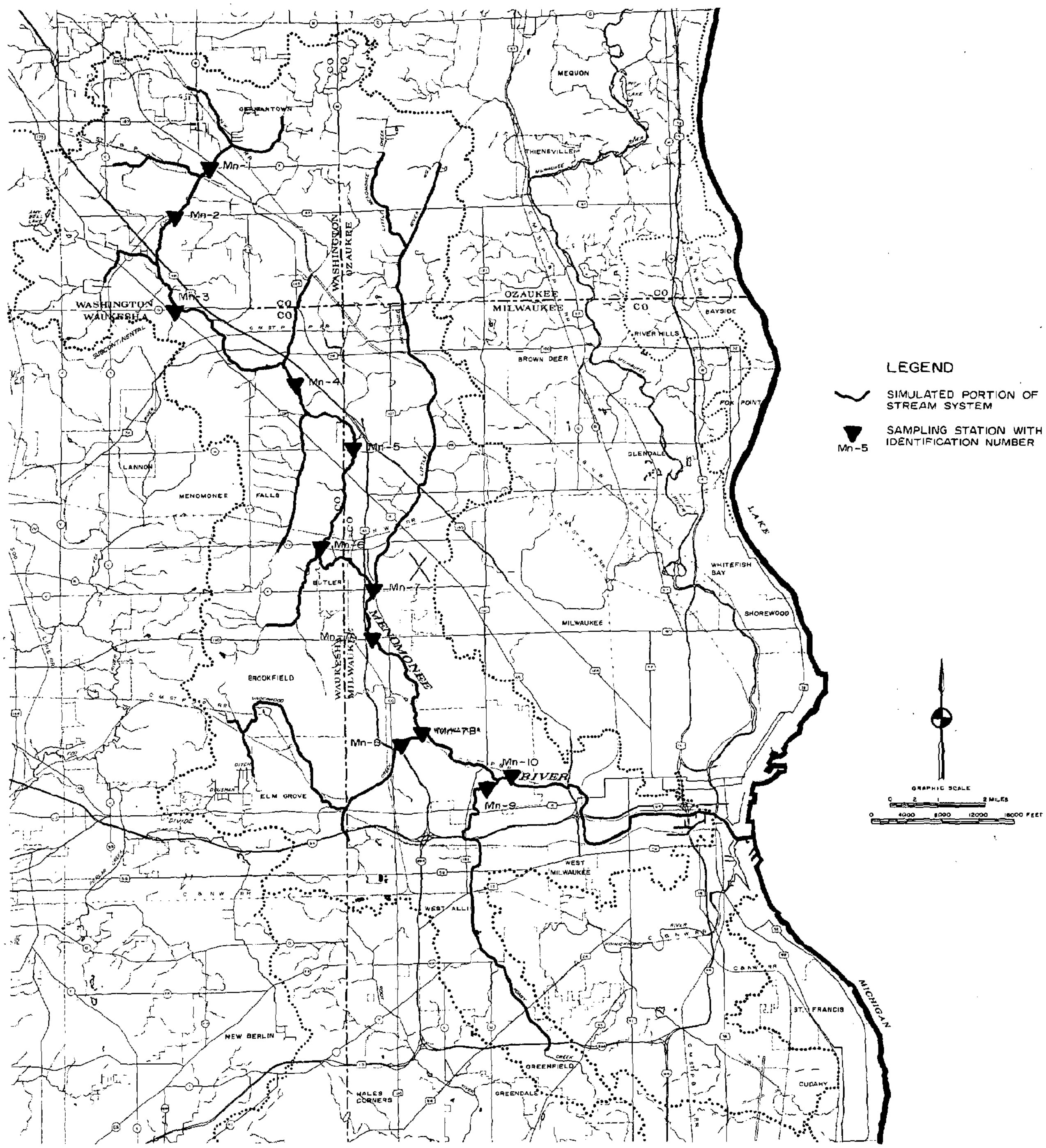
The samples were analyzed for up to 32 chemical, physical, biochemical, and bacteriological water quality indicators for the purpose of assessing the then-existing condition of stream water quality in relation to pollution sources, land use, and population distribution and concentration. The study is described in SEWRPC Technical Report No. 4, Water Quality and the Flow of Streams in Southeastern Wisconsin, 1966.

SEWRPC Continuing Water Quality Monitoring Program: 1968-1974: In 1968 the Commission entered into a cooperative agreement with the Wisconsin Department of Natural Resources for the conduct of a continuing stream water quality monitoring program within the Region. The objective of the program is to provide, on a continuing basis, the water quality information necessary to assess the long-term trends in water quality within the rapidly urbanizing seven-county Region.

The continuing monitoring program was designed to build upon the bench mark stream water quality data base established by the Commission in the initial 1964-1965

Map 59

LOCATION OF SEWRPC STREAM SAMPLING STATIONS IN THE MENOMONEE RIVER WATERSHED: 1964-1974



In 1964, the Commission began a stream water quality sampling program in the watershed using the 12 stream water quality sampling stations shown above. Data obtained from that sampling program were useful in identifying the type and cause of surface water pollution in the Menomonee River watershed.

Source: SEWRPC.

SEWRPC stream water quality study and, accordingly, the monitoring network included the 12 Menomonee River watershed stations shown on Map 59. The SEWRPC stream water quality monitoring program involved, during 1968 and 1969, twice yearly sampling at all stations during the periods of high and low flow, with the samples being analyzed for dissolved oxygen, temperature, fecal and total coliform, nitrate nitrogen, nitrite nitrogen, dissolved phosphorus, pH, chloride, and specific conductance.

To provide additional information on the diurnal fluctuations of stream water quality, the monitoring program was revised in 1970 to provide for the collection of six stream water samples over a 24-hour period once yearly during the period of low streamflow at each sampling station, with each sample being analyzed for the following five parameters: dissolved oxygen, temperature, pH, chloride, and specific conductance. In addition, once during the 24-hour period the following four parameters would be analyzed: fecal coliform, nitrate nitrogen, nitrite nitrogen, and dissolved phosphorus.

In order to obtain regional information on additional water quality indicators, the Commission and the DNR agreed to a further revision of the program beginning with the 1972 survey. The overall continuity of the sampling program was maintained by continuing to monitor those parameters included in previous surveys with the following changes: a decrease from six to four per day in the frequency of dissolved oxygen, temperature, and specific conductance measurements; a decrease from six to two per day in the frequency of chloride determinations; an increase from one to two per day in the frequency of fecal coliform, nitrate nitrogen, nitrite nitrogen, and dissolved phosphorus measurements; and the addition of two determinations per day of organic nitrogen, ammonia nitrogen, and total phosphorus. The addition of these latter three parameters was prompted by the need for more regional information on nutrients and increased interest in both oxygen demand exerted by ammonia nitrogen and the toxic effect of ammonia nitrogen.

Thus, the stream water quality monitoring program, as revised in 1972 and as continued through 1975, provides for four measurements over a 24-hour period once yearly. These measurements are made during the period of low flow at each of the 87 stations for each of the following three parameters: dissolved oxygen, temperature, and specific conductance. Two determinations are made at each station over the same 24-hour period for each of the following nine parameters: pH, chloride, fecal coliform, nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, organic nitrogen, dissolved phosphorus, and total phosphorus.

Data resulting from the 1968-1975 sampling program are available for inspection in Commission files. These data were analyzed under the planning program and a data summary and corresponding discussion appear in a subsequent section of this chapter.

Eutrophic Evaluation Study: 1968-1969: The Menomonee River watershed was the subject of an extensive field study from April 1968 to December 1969, and the results were published as : Zanoni, A., "Eutrophic Evaluation of a Small Multi-Land Use Watershed," U. W. Water Resources Center Technical Report, June 1970. The purpose of this investigation was to determine the effects of runoff events, seasons, and land use and sewage treatment plants on the quantity of the nutrient phosphorus transported in the stream system. A total of 30 wet and dry condition period sampling surveys were carried out during the two-year study period with samples being taken at 15 sites. All samples were analyzed for total soluble phosphate, and some total phosphorus analyses were conducted. Phosphorus determinations were also made on samples of the effluent from the Menomonee Falls and Germantown sewage treatment plants in the late summer of 1968 and of 1969.

Creosote Study: 1972: This study was conducted by members of the Citizens for Menomonee River Restoration, Inc., (CMRR) on the Little Menomonee River in June, July, and August of 1972 as a result of serious chemical burns received by participants in a river clean-up sponsored by CMRR on June 5 of that year. The objective of the study was to investigate and document the extent and source of what appeared to be creosote in the bottom muds of the Little Menomonee River. Creosote is obtained by fractional distillation of coal tar and is used as a preservative for wood products such as telephone poles and railroad ties. It is similar in appearance to oil and insoluble in and heavier than water. Study findings were published as: Citizens for Menomonee River Restoration, The Creosote Problem in the Little Menomonee River, no date, 67 pp.

Preliminary IJC Menomonee River Pilot Watershed Study Data: 1973-1974: The Wisconsin Department of Natural Resources initiated a preliminary water quality sampling program in the Menomonee River watershed in February 1973 in anticipation of including the watershed in the International Joint Commission's study of Great Lakes pollution from land surface runoff. Three grab sample sites were established on the stream system: at the N. 70th Street crossing on the Menomonee River which coincides with the location of the U. S. Geological Survey wire weight stream gage, at the N. 124th Street crossing of the Menomonee River in the Village of Butler, which is also the Milwaukee-Waukesha County line, and on the Little Menomonee River at W. Villard Avenue extended in the City of Milwaukee. The sampling program was initiated on February 22, 1973 and continued on an approximately twice-weekly to monthly basis through October 1974. While a full range of water quality analyses was conducted on the samples, the suspended sediment, heavy metals, and ammonia data are of particular importance to the Menomonee River watershed planning program because of the paucity of such data from other sources. Data for the period February 22, 1973, through March 1974 were used in the preparation of this chapter.

Synoptic Water Quality Surveys: 1973-1974: Three 24-hour synoptic water quality surveys were conducted on April 4-5, 1973, July 18-19, 1973, and August 6-7, 1974, under the Menomonee River watershed planning program. These surveys were synoptic in that they involved water quality determinations made on a large number of samples obtained from many locations throughout the watershed during the same approximately 24-hour sampling period. Such a synoptic survey is intended to "capture" the water quality characteristics of a watershed during a relatively short time interval, thereby revealing the spatial and temporal variations in water quality phenomena. The water quality surveys were a cooperative effort conducted jointly by the Commission, the Wisconsin Department of Natural Resources, and the U. S. Geological Survey.

The objective of the three synoptic surveys was to provide the following information: an indication of the types and relative amount of pollutants contributed by point sources, such as municipal and industrial wastewater treatment plants; a determination of the nature and quantity of pollutants contained in surface runoff from a range of urban and rural land uses existing in the watershed; and a measure of the condition of the surface waters of the major streams in the watershed relative to the recommended water use objectives and supporting water quality standards. The water quality surveys also were intended to provide background water quality data and other information needed for the development, calibration, and application of the water quality model being used in the watershed study.

In each of these surveys, streamflow measurements were made at five locations on the stream system, while physical, chemical, and biological quality indicators were measured at 17 instream sampling sites. In addition, the surveys involved the conduct of water quality analyses on the effluent from up to five municipal sewage treatment plants and two industrial facilities, and on the runoff from four watershed subareas, each exhibiting a different type of land use.

As shown on Map 60, the five streamflow measuring stations included the USGS wire weight gage on the Menomonee River in Wauwatosa, the USGS partial record gage on the Little Menomonee River in Mequon, the partial record gage on the Menomonee River between Germantown and Menomonee Falls, and two temporary gaging sites: one on Underwood Creek at its confluence with the Menomonee River and one on Honey Creek at its confluence with the Menomonee River. The 17 instream sampling stations, which included the 12 stations used in earlier Commission water quality surveys, were distributed throughout the watershed stream system as follows: 11 of the Menomonee River, 2 on the Little Menomonee River, 2 on Underwood Creek, and 2 on Honey Creek. The five municipal sewage treatment plants included in the survey were the two Village of Germantown treatment facilities, the two Village of Menomonee Falls plants, and the Village of Butler overflow-chlorination facility. The S. K. Williams Company in the City of Wauwatosa and the Milwaukee Road railroad in the Menomonee industrial valley were the two industrial discharges included in the survey. The four special land use stations were located, as shown on Map 60, on 1) a natural creek in the City of Mequon carrying runoff from a 3.26-square-mile rural, agricultural area; 2) a storm water channel in the City of Milwaukee conveying runoff from a 2.15-square-mile newer, primarily residential area served by a separate sewer system; 3) a storm sewer in the City of Wauwatosa carrying runoff from an older, primarily residential 0.36-square-mile area served primarily by a separate sewer system; and 4) a combined sewer outfall at Hawley Road in the City of Milwaukee conveying discharge from a 0.73-square-mile older, primarily residential area served by a combined sewer system.

All of the raw data resulting from the three synoptic surveys are set forth in tabular form in Appendices C, D, and E of this volume of the report. Data summaries and selected raw data are presented in tabular and graphical form elsewhere in this chapter.

Municipal Sewage Treatment Facilities

Five municipal sewage treatment facilities existed in the Menomonee River watershed at the initiation of the watershed planning program in 1972: the Village of Germantown Old Village and County Line Road sewage treatment plants, the Village of Menomonee Falls Pilgrim Road and Lilly Road sewage treatment plants, and the Village of Butler sewage overflow and chlorination facility. The small Village of Germantown County Line Road sewage treatment plant was permanently removed from service on November 2, 1973, upon completion of a force main from that site to the Old Village sewage treatment plant.

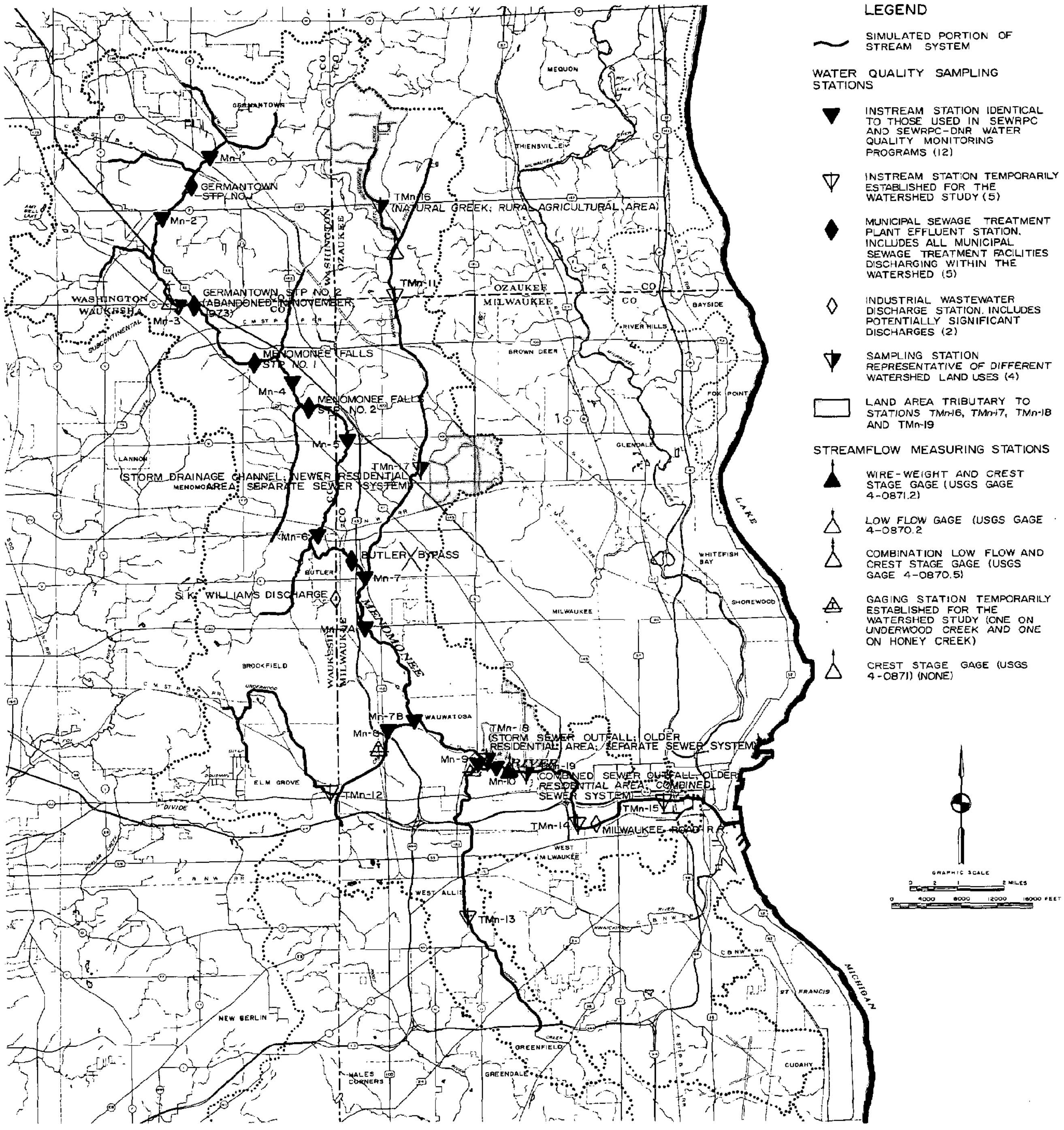
The following discussions of each of the five municipal sewage treatment facilities include data and information about the location of the facility, the manner in which it is financed and operated, the history of its construction and subsequent development, the size and characteristics of the service area, the level of treatment and the type of treatment process, and the hydraulic capacity of the facility and the quality of the discharge. Recommendations of the adopted regional sanitary sewerage system plan[27] as they affect each plant are discussed as are the steps that have been or will be undertaken to accomplish those recommendations. The base year in the report for sewage treatment facility discussions is 1970 except for instances where major sewage treatment facilities changes have occurred since that time or where significant additional effluent water quality data have been obtained.

Village of Germantown Old Village Sewage Treatment Plant: As shown on Map 60, this sewage treatment plant is located immediately east of the Menomonee River about one mile west of the center of the Old Village area

[27] *Southeastern Wisconsin Regional Planning Commission, A Regional Sanitary Sewerage System Planning Program for Southeastern Wisconsin, Planning Report No. 16, February 1974, 809 pp.*

Map 60

LOCATION OF MONITORING STATIONS USED FOR SYNOPTIC WATER QUALITY SURVEYS IN THE MENOMONEE RIVER WATERSHED ON APRIL 4, 1973; JULY 18, 1973; AND AUGUST 6, 1974



Three synoptic water quality surveys were undertaken as a part of the watershed study to provide information on the types and amounts of pollutants contributed by point sources; to determine the nature and quantity of pollutants contained in surface runoff from a range of urban and rural land surfaces existing in the watershed; and to measure the condition of the surface waters of the major streams in the watershed against the recommended water use objectives and supporting water quality standards. The water quality surveys also were intended to provide background water quality data and other information needed for the development, calibration, and application of the water quality model being used in the watershed study.

Source: SEWRPC.

of the Village of Germantown. Selected information for this and other municipal sewage treatment plants in the Menomonee River watershed is set forth in Tables 41 and 42. Management of the Village of Germantown sanitary sewerage system is under the direction of the Village Board. Day-to-day administration of the system is provided by a regular full-time licensed operator. Financing of the system is provided through the general property tax and a sewer service charge based on a flat quarterly rate to residences and a volumetric rate to commercial users.

Service Area: In 1970 the Old Village treatment plant served about 1,400 persons residing in a 0.4-square-mile area as shown on Map 12. As of 1975, the Old Village facility currently serves about 4,400 persons in a 2.5-square-mile area as a result of the November 1973 abandonment of the County Line facility and the post-1970 development of the Lake Park Village housing project. The entire area tributary to the Old Village plant is served by a separate sewer system.

Type and Level of Treatment: The treatment plant is composed of two parallel sewage treatment facilities only one of which discharges effluent to the Menomonee River. The first of the two parallel plants, a trickling filter type plant, was constructed in 1956 and put out of operation in 1972. The second plant, an extended aeration activated sludge type plant, was constructed in 1969 and continues to operate. Advanced waste treatment capability consisting of phosphorus removed by a pickle liquor process and a 10 million gallon final sedimentation pond were added to the treatment plant in 1974.

The average hydraulic design capacity of the plant is 1.0 mgd, with an estimated combined peak hydraulic design capacity of 2.3 mgd. The average hydraulic loading on the combined plant in 1970 was estimated at 0.4 mgd, indicating that the plant had ample capacity to treat the average daily flow from the existing sewer service area. The average hydraulic loading on the plant in 1975 was estimated at less than 1.0 mgd indicating that the treatment facility continues to have adequate capacity to treat the average daily flow from the sewer service area even though that area was considerably enlarged since 1970. The treatment process provided by the activated sludge type plant in combination with the recently added phosphorus removal capability is classified as advanced level.

Recommendations of the Regional Sanitary Sewerage System Plan and Implementation Status: The adopted regional sanitary sewerage system plan recommended the eventual abandonment of the Old Village sewage treatment plant. The Village of Germantown and the Milwaukee-Metropolitan Sewerage Commissions have agreed in principle to the future connection of the Germantown sewer service area to the Milwaukee-Metropolitan sewerage system with sewage treatment to be accomplished at the Commissions' Jones Island and South Shore treatment plants located on the Lake Michigan shoreline. At the present time, trunk sewer service to the Village of Germantown is not available. Until such time as trunk sewer service from the Milwaukee-Metropolitan sewerage system becomes available, the Village of Germantown is continuing to operate the Old Village facility. At the time trunk sewer service becomes available from the Milwaukee-Metropolitan sewerage system, the Village intends to construct a series of force mains and pumping stations to connect the Old Village area plants to the Milwaukee-Metropolitan system. It is anticipated that the Village's sanitary sewer system will be connected to the Milwaukee-Metropolitan system by 1981 at which time the Old Village sewage treatment plant will be abandoned. It is anticipated that this connection will serve the needs of a planned approximately 11-square-mile service area in the Village of Germantown through the year 2000. Eventually, gravity trunk sewers will be extended to serve the Village of Germantown.

Village of Germantown County Line Sewage Treatment Plant: As shown on Map 60, this sewage treatment plant, which discharged its effluent to the Menomonee River, was located immediately east of the River at the south Village limits near the Washington-Waukesha County line until its abandonment in November 1973. Selected information about this treatment facility is set forth in Table 41.

Service Area and Type of Treatment: The County Line treatment plant served about 1,000 persons in an approximately 0.1-square-mile subdivision as shown on Map 12. The activated sludge type plant, which was constructed in 1963, had an average hydraulic design capacity of 0.05 mgd with an estimated peak hydraulic design capacity of 0.10 mgd. The treatment processes provided by the plant were classified as secondary level.

Recommendations of the Regional Sanitary Sewerage System Plan and Implementation Status: The adopted regional sanitary sewerage system plan endorsed the planned abandonment of the County Line sewage treatment plant, a recommendation that was accomplished in November 1973 upon completion of a 2.3-mile-long 12-inch-diameter force main from the County Line facility to the Old Village sewage treatment plant. As noted above, the sewerage system plan recommended the eventual abandonment of the latter facility via a connection of it by trunk sewer to the Milwaukee-Metropolitan sewerage system.

Village of Menomonee Falls Pilgrim Road Sewage Treatment Plant: This sewage treatment plant is, as shown on Map 60, located immediately north of the Menomonee River and east of Pilgrim Road and discharges to the Menomonee River. Selected information about this treatment facility is set forth in Table 41. Management of the Village of Menomonee Falls sanitary sewerage system is under the direction of the Village Board. Day-to-day administration of the system is provided by the Village Public Works Department.

Service Area: In 1970 the Pilgrim Road treatment plant, in conjunction with the Village's Lilly Road treatment plant, served about 17,400 persons in a combined area of about 3.8 square miles as shown on Map 12. The entire area is served by a separate sewer system.

Table 41

SELECTED CHARACTERISTICS OF PUBLIC SEWAGE TREATMENT FACILITIES IN THE MENOMONEE RIVER WATERSHED: 1970

Name	Estimated Total Area Served (square miles)	Estimated Total Population Served	Dates of Original Construction and Major Modifications	Treatment Provided		Receiving Stream	Population[a]	Design Capacity			
				Type	Level			Average Hydraulic (mgd)	Peak Hydraulic (mgd)	Average Organic (pounds $CBOD_5$/day)	Population Equivalent[a]
Village of Germantown Old Village Plant[b]	0.42	1,400	1956, 1969	Trickling Filter and Activated Sludge	Secondary	Menomonee River	11,000	1.20	2.90	2,385	11,400
Village of Germantown County Line Road Plant[c]	0.14	1,000	1963	Activated Sludge	Secondary	Menomonee River	N/A	0.05	0.10	85	400
Village of Menomonee Falls Pilgrim Road Plant	3.77	17,400	1954,1962	Trickling Filter and Activated Sludge	Secondary	Menomonee River	N/A	1.9	2.5	935	4,450
Village of Menomonee Falls Lilly Road Plant			1969	Activated Sludge and Flow-Through Lagoon	Tertiary	Menomonee River	N/A	1.0	2.0	1,700	8,100
Village of Butler Overflow Chlorination Facility	0.8	2,300	N/A	Chlorination	--	Menomonee River	N/A	N/A	N/A	N/A	N/A

NOTE: N/A indicates data not available.

[a] *The population design capacity for a given sewage treatment facility was obtained directly from engineering reports prepared by or for the local unit of government operating the facility and reflects assumptions made by the design engineer. The population equivalent design capacity was estimated by the Commission staff by dividing the design $CBOD_5$ loading in pounds per day, as set forth in the engineering reports, by an estimated per capita contribution of 0.21 pound of $CBOD_5$ per day. If the design engineer assumed a different daily per capita contribution of $CBOD_5$, the population equivalent design capacity will differ from the population design capacity shown in the table.*

[b] *Phosphorus removal and final sedimentation facilities were added in 1974. As a result of the November 1973 abandonment of the Village's County Line facility, and the development of Lake Park Village, the Old Village sewage treatment plant now serves about 2.5 square miles containing approximately 4,400 persons. The trickling filter plant was put out of operation in 1972. The peak hydraulic design capacity of the remaining activated sludge plant is 2.3 mgd, and the average hydraulic design capacity of the remaining plant is 1.0 mgd.*

[c] *Permanently removed from service on November 2, 1973.*

Source: SEWRPC.

Type and Level of Treatment: The original plant, a trickling filter type, was constructed in 1954. In 1962 a new activated sludge plant was constructed to operate in parallel with the trickling filter plant. The average hydraulic design capacity of this combined plant is 1.9 mgd, with a peak hydraulic design capacity of 2.5 mgd. The average hydraulic loading on the plant in 1970 was estimated at 1.7 mgd, indicating that the plant had adequate capacity to treat the average daily flow from the sewer service area. The treatment processes provided by both the trickling filter and activated sludge type plants are classified as secondary level.

Recommendations of the Regional Sanitary Sewerage System Plan and Implementation Status: The adopted regional sanitary sewerage system plan recommended the eventual abandonment of the Village of Menomonee Falls Pilgrim Road sewage treatment plant as well as the Lilly Road facility. The Village of Menomonee Falls is committed by contract to abandon its temporary sewage treatment facilities and connect to the Milwaukee-Metropolitan sewerage system as soon as the trunk sewer capacity is provided by the Milwaukee-Metropolitan Sewerage Commissions on the Milwaukee-Waukesha County line at STH 45. At the present time, it is anticipated that this trunk sewer will be in place and that gravity flow will be initiated by 1981. The Village has completed a trunk sewer link between the two treatment plants and the Waukesha-Milwaukee County line. That sewer is temporarily connected by a pumping station to the Milwaukee-Metropolitan system and the Village is authorized to pump 500,000 gallons of sewage into the Milwaukee-Metropolitan system from midnight to 6:00 a.m. each day provided that dry weather conditions exist. Almost all of the 18.7-square-mile portion of the Village of Menomonee Falls lying within the watershed lies within the contract service area of the Milwaukee-Metropolitan Sewerage Commissions.

Table 42

SEWAGE TREATMENT PLANT EFFLUENT CHARACTERISTICS DURING THE SYNOPTIC WATER QUALITY SURVEYS

Synoptic Water Quality Survey No. 1—April 4, 1973

Germantown Old Village Plant

Parameter	Units	0515	1050	1600	2255	Average	Total Transport (lbs/day)
Temperature	°F	64.4	68.0	69.8	68.0	67.6	–[a]
Dissolved Oxygen	Mg/L	7.0	7.3	7.1	7.0	7.1	–[a]
pH	S.U.	7.8	7.9	7.8	7.8	7.8	–[a]
Fecal Coliforms	MFFCC/ 100 ml	–[b]	–[b]	–[b]	–[b]	–[b]	–[a,b]
Chlorides	Mg/L	129	260	231	202	208	979
Conductivity	MM/cm	1,243	1,681	1,524	1,465	1,478.2	–[a]
Turbidity	Mg/L	1.40	2.00	1.70	1.50	1.65	–[a]
NO_2-N	Mg/L	1.361	0.205	0.135	0.033	0.434	2
NO_3-N	Mg/L	0.59	2.55	4.31	4.33	2.95	14
NH_3-N	Mg/L	0.74	1.02	0.61	0.18	0.63	3
Org-N	Mg/L	1.69	2.88	1.23	2.71	2.13	10
Total N	Mg/L	4.38	6.65	6.29	7.23	6.14	29
PO_4-P	Mg/L	8.963	7.801	8.904	7.606	8.344	40
Total P	Mg/L	8.10	8.00	9.50	8.21	8.20	39
$CBOD_5$	Mg/L	3.7	-	-	2.1	2.9	14
$NBOD_5$	Mg/L	1.6	-	-	1.3	1.5	7
$TBOD_5$	Mg/L	5.3	2.5	1.5	3.4	3.2	15
Discharge	Mgd/cfs	0.45 / 0.70	0.47 / 0.73	0.45 / 0.70	0.92 / 1.43	0.57 / 0.89	–[a]

Germantown County Line Plant

Parameter	Units	0535	1115	1715	2310	Average	Total Transport (lbs/day)
Temperature	°F	60.8	62.5	64.4	62.5	62.55	–[a]
Dissolved Oxygen	Mg/L	3.2	3.8	4.7	3.8	3.9	–[a]
pH	S.U.	8.0	7.9	7.9	7.9	7.92	–[a]
Fecal Coliforms	MFFCC/ 100 ml	–[b]	–[b]	–[b]	–[b]	–[b]	–[a,b]
Chlorides	Mg/L	390	429	501	438	440	–[c]
Conductivity	MM/cm	2,042	2,173	2332	2,260	2,201.8	–[a]
Turbidity	Mg/L	4.30	3.50	4.20	5.30	4.32	–[a]
NO_2-N	Mg/L	0.873	1.243	1.264	1.641	1.255	–[c]
NO_3-N	Mg/L	0.63	1.38	1.17	1.50	1.165	–[c]
NH_3-N	Mg/L	12.41	10.87	11.04	8.09	10.60	–[c]
Org-N	Mg/L	3.81	3.30	3.61	4.14	3.69	–[c]
Total N	Mg/L	17.82	16.77	16.98	15.27	16.71	–[c]
PO_4-P	Mg/L	4.290	4.614	4.437	5.441	4.696	–[c]
Total P	Mg/L	4.17	9.01	4.96	4.74	5.72	–[c]
$CBOD_5$	Mg/L	11.0	12.0	11.0	13.0	11.8	–[c]
$NBOD_5$	Mg/L	> 9.0	13.0	10.0	15.0	> 11.8	–[c]
$TBOD_5$	Mg/L	> 20.8	26.0	21.0	28.0	> 23.8	–[c]
Discharge	Mgd/cfs	N/A	N/A	N/A	N/A	N/A	–[a]

Menomonee Falls Pilgrim Road Plant

Parameter	Units	0545	1125	1630	2320	Average	Total Transport (lbs/day)
Temperature	°F	68.0	70.7	74	70.7	70.7	–[a]
Dissolved Oxygen	Mg/L	6.7	6.6	8.2	6.1	8.4	–[a]
pH	S.U.	7.7	7.7	7.6	7.8	7.7	–[a]
Fecal Coliforms	MFFCC/ 100 ml	–[b]	–[b]	–[b]	–[b]	–[b]	–[a,b]
Chlorides	Mg/L	187	424	202	173	247	3,048
Conductivity	MM/cm	1,437	2,124	1,504	1,411	1,619	–[a]
Turbidity	Mg/L	5.10	13.00	15.00	25.00	14.62	–[a]
NO_2-N	Mg/L	0.776	1.073	0.800	0.866	0.879	11
NO_3-N	Mg/L	6.30	6.69	5.73	4.48	5.880	72
NH_3-N	Mg/L	1.33	8.97	7.49	7.29	6.27	77
Org-N	Mg/L	3.15	4.10	4.24	7.03	4.63	57
Total N	Mg/L	11.56	20.83	18.26	19.65	17.58	217
PO_4-P	Mg/L	5.145	4.422	4.260	5.396	4.806	59
Total P	Mg/L	5.42	3.99	4.96	6.22	5.15	64
$CBOD_5$	Mg/L	4.0	6.4	5.5	12.0	7.0	86
$NBOD_5$	Mg/L	6.0	4.6	1.6	10.0	5.6	69
$TBOD_5$	Mg/L	10.0	11.0	7.1	22.0	12.5	154
Discharge	Mgd/cfs	N/A	N/A	N/A	N/A	1.48[d] / 2.29	–[a]

Menomonee Falls Lilly Road Plant

Parameter	Units	0735	1135	1650	2335	Average	Total Transport (lbs/day)
Temperature	°F	69.8	74.1	77.0	75.2	74.5	-
Dissolved Oxygen	Mg/L	9.2	5.1	5.7	5.1	6.3	-
pH	S.U.	8.6	8.5	8.5	8.4	8.6	-
Fecal Coliforms	MFFCC/ 100 ml	<100	<100	<100	<100	<100	–[a]
Chlorides	Mg/L	255	274	298	298	281	1,734
Conductivity	MM/cm	1,805	1,781	1,772	1,800	1,784.5	–[a]
Turbidity	Mg/L	10.00	7.70	11.00	8.00	9.42	–[a]
NO_2-N	Mg/L	0.076	0.307	0.072	0.188	0.156	1
NO_3-N	Mg/L	0.15	0.28	0.14	0.28	0.20	1
NH_3-N	Mg/L	3.82	7.07	4.64	6.08	5.58	34
Org-N	Mg/L	5.82	5.36	6.96	5.33	6.17	38
Total N	Mg/L	9.87	13.60	11.83	12.84	12.04	74
PO_4-P	Mg/L	3.478	4.437	4.260	4.910	4.271	26
Total P	Mg/L	3.48	4.85	4.79	5.62	4.94	30
$CBOD_5$	Mg/L	14.0	>30.0	16.0	16.0	>19.0	>117
$NBOD_5$	Mg/L	17.0	> 0.0	14.0	13.0	11.0	> 68
$TBOD_5$	Mg/L	31.0	> 30.0	30.0	29.0	>30.0	> 185
Discharge	Mgd/cfs	N/A	N/A	N/A	N/A	0.74[d] / 1.16	–[a]

Butler Bypass and Chlorination Facility

Parameter	Units	0610	1200	1715	2355	Average	Total Transport (lbs/day)
Temperature	°F	62.5	68.0	68.0	66.2	66.2	–[a]
Dissolved Oxygen	Mg/L	7.5	4.9	4.3	N/A	5.6	–[a]
pH	S.U.	9.5	7.8	8.8	8.4	8.65	–[a]
Fecal Coliforms	MFFCC/ 100 ml	–[a]	–[a]	–[a]	–[a]	–[a]	–[a,b]
Chlorides	Mg/L	419	158	40	78	173	–[c]
Conductivity	MM/cm	2,210	1,362	1,187	1,313	1,518	–[a]
Turbidity	Mg/L	36.00	53.00	61.00	55.00	51.25	–[a]
NO_2-N	Mg/L	0.060	0.071	0.101	0.122	0.088	–[c]
NO_3-N	Mg/L	0.47	1.63	0.68	1.19	0.99	–[c]
NH_3-N	Mg/L	3.43	20.93	18.55	29.09	17.49	–[c]
Org-N	Mg/L	6.68	8.30	8.50	13.81	9.34	–[c]
Total N	Mg/L	10.54	31.02	25.83	44.16	27.91	–[c]
PO_4-P	Mg/L	0.280	0.725	3.598	1.915	1.627	–[c]
Total P	Mg/L	0.52	2.08	7.21	5.05	3.715	–[c]
$CBOD_5$	Mg/L	> 32.0	> 32.0	> 30.0	> 30.0	> 31.0	–[c]
$NBOD_5$	Mg/L	> 0.0	> 0.0	> 0.0	> 0.0	> 0.0	–[c]
$TBOD_5$	Mg/L	> 32.0	> 32.0	> 30.0	> 30.0	> 31.0	–[c]
Discharge	Mgd/cfs	N/A	N/A	N/A	N/A	N/A	–[a]

Synoptic Water Quality Survey No. 2—July 18, 1973

Germantown Old Village Plant

Parameter	Units	0505	1000	1655	2250	Average	Total Transport (lbs/day)
Temperature	°F	49.1	50.0	50.0	50.0	49.8	–[a]
Dissolved Oxygen	Mg/L	7.7	7.8	7.0	7.2	7.4	–[a]
pH	S.U.	7.9	7.8	7.7	7.8	7.8	–[a]
Fecal Coliforms	MFFCC/ 100 ml	–[b]	–[b]	–[b]	–[b]	–[b]	–[a,b]
Chlorides	Mg/L	148	197	158	148	163	1,237
Conductivity	MM/cm	1,215	1,338	1,224	1,190	1,241	–[a]
Turbidity	Mg/L	3.4	3.8	6.8	4.0	4.4	–[a]
NO_2-N	Mg/L	1.871	0.284	2.789	0.106	1.188	9
NO_3-N	Mg/L	2.99	4.13	0.33	0.06	1.88	14
NH_3-N	Mg/L	1.02	2.00	1.88	1.72	1.66	13
Org-N	Mg/L	1.33	1.22	1.89	1.31	1.44	11
Total N	Mg/L	6.81	7.63	6.89	3.20	6.16	47
PO_4-P	Mg/L	8.403	8.168	7.008	11.913	9.022	68
Total P	Mg/L	9.18	8.87	9.24	10.23	9.33	71
$CBOD_5$	Mg/L	<10.0	<10.0	<13.0	<10.0	<10.8	<82
$NBOD_5$	Mg/L	> 0.0	> 0.0	> 4.0	> 0.0	> 1.0	> 8
$TBOD_5$	Mg/L	<13.0	<10.0	<17.0	<0.0	<4.18	90
Discharge	Mgd/cfs	0.81 / 1.26	0.82 / 1.26	0.96 / 1.49	0.94 / 1.46	0.91 / 1.41	–[a]

Germantown County Line Plant

Parameter	Units	0530	1120	1715	2310	Average	Total Transport (lbs/day)
Temperature	°F	44.5	45.5	45.5	48.4	45.6	–[a]
Dissolved Oxygen	Mg/L	7.8	8.9	8.7	7.7	8.3	–[a]
pH	S.U.	8.1	8.0	8.1	8.2	8.1	–[a]
Fecal Coliforms	MFFCC/ 100 ml	–[b]	–[b]	–[b]	–[b]	–[b]	–[a,b]
Chlorides	Mg/L	313	487	342	291	353	–[c]
Conductivity	MM/cm	1,736	2,082	1,879	1,638	1,833.8	–[a]
Turbidity	Mg/L	6.8	11.5	12.0	7.0	8.8	–[a]
NO_2-N	Mg/L	0.153	0.68	0.32	0.121	0.318	–[c]
NO_3-N	Mg/L	0.22	0.32	0.19	0.09	0.20	–[c]
NH_3-N	Mg/L	7.37	6.35	6.09	7.20	6.75	–[c]
Org-N	Mg/L	1.86	1.68	1.30	1.50	1.54	–[c]
Total N	Mg/L	9.40	9.03	7.90	8.91	8.81	–[c]
PO_4-P	Mg/L	4.420	2.207	2.207	3.417	2.611	–[c]
Total P	Mg/L	4.89	3.02	2.97	5.39	4.08	–[c]
$CBOD_5$	Mg/L	11.0	16.0	11.0	18.0	13.5	–[c]
$NBOD_5$	Mg/L	10.0	4.0	12.0	14.0	10.0	–[c]
$TBOD_5$	Mg/L	21.0	20.0	23.0	30.0	23.5	–[c]
Discharge	Mgd/cfs	N/A	N/A	N/A	N/A	N/A	–[a]

Menomonee Falls Pilgrim Road Plant

Parameter	Units	0540	1130	1730	2320	Average	Total Transport (lbs/day)
Temperature	°F	53.6	53.6	53.6	53.6	53.6	–[a]
Dissolved Oxygen	Mg/L	6.7	8.0	7.8	6.0	7.8	–[a]
pH	S.U.	7.8	7.8	7.8	7.7	7.78	–[a]
Fecal Coliforms	MFFCC/ 100 ml	–[b]	–[b]	–[b]	–[b]	–[b]	–[a,b]
Chlorides	Mg/L	386	279	216	284	291	5,216
Conductivity	MM/cm	1,934	1,853	1,414	1,637	1,659.2	–[a]
Turbidity	Mg/L	13.5	15.0	15.0	16.0	14.8	–[a]
NO_2-N	Mg/L	0.368	0.512	0.55	0.651	0.495	9
NO_3-N	Mg/L	5.48	5.05	4.60	3.64	4.70	84
NH_3-N	Mg/L	3.39	7.98	4.48	4.71	5.14	92
Org-N	Mg/L	2.29	2.63	2.17	2.63	2.42	43
Total N	Mg/L	11.40	16.17	11.88	11.58	12.75	229
PO_4-P	Mg/L	3.181	3.919	6.190	5.305	4.649	83
Total P	Mg/L	4.70	6.93	7.13	6.87	6.41	115
$CBOD_5$	Mg/L	<10.0	<10.0	<10.0	<11.0	<10.3	<185
$NBOD_5$	Mg/L	> 0.0	> 0.0	>5.0	> 3.0	> 2.0	>36
$TBOD_5$	Mg/L	10.0	10.0	18.0	14.0	12.3	220
Discharge	Mgd/cfs	N/A	N/A	N/A	N/A	2.16[e] / 3.33	–[a]

Menomonee Falls Lilly Road Plant

Parameter	Units	0555	1145	1750	2335	Average	Total Transport (lbs/day)
Temperature	°F	44.6	44.6	44.6	44.6	44.6	–[a]
Dissolved Oxygen	Mg/L	9.7	10.2	10.3	10.0	10.05	–[a]
pH	S.U.	8.1	8.1	8.1	8.1	8.1	–[a]
Fecal Coliforms	MFFCC/ 100 ml	240	30	60	100	182.5	–[a]
Chlorides	Mg/L	313	312	313	313	313	2,141
Conductivity	MM/cm	1,788	1,826	1,773	1,798	1,796.8	–[a]
Turbidity	Mg/L	4.0	4.9	4.8	4.5	4.55	–[a]
NO_2-N	Mg/L	0.624	0.609	0.688	0.576	0.634	4
NO_3-N	Mg/L	0.51	1.03	0.50	0.65	0.62	4
NH_3-N	Mg/L	6.42	7.82	6.63	7.48	7.09	48
Org-N	Mg/L	1.67	1.48	1.80	1.47	1.52	10
Total N	Mg/L	9.32	10.91	9.32	9.93	9.87	67
PO_4-P	Mg/L	6.19	6.869	6.220	6.544	6.456	44
Total P	Mg/L	7.33	8.04	7.01	8.18	7.64	52
$CBOD_5$	Mg/L	3.7	N/A	3.1	3.7	3.5	49
$NBOD_5$	Mg/L	4.9	N/A	3.6	4.3	4.5	31
$TBOD_5$	Mg/L	8.6	6.1	6.7	8.5	7.7	52.78
Discharge	Mgd/cfs	N/A	N/A	N/A	N/A	0.82[e] / 1.27	–[a]

Butler Bypass and Chlorination Facility

Parameter	Units	0615	-	-	-	Average	Total Transport (lbs/day)
Temperature	°F	49.1	N/A	N/A	N/A	49.1	–[a]
Dissolved Oxygen	Mg/L	9.2	N/A	N/A	N/A	9.2	–[a]
pH	S.U.	7.9	N/A	N/A	N/A	7.9	–[a]
Fecal Coliforms	MFFCC/ 100 ml	–[b]	–[b]	–[b]	–[b]	–[b]	–[a,b]
Chlorides	Mg/L	153	N/A	N/A	N/A	153	–[c]
Conductivity	MM/cm	1,290	N/A	N/A	N/A	1,290	–[a]
Turbidity	Mg/L	16.0	N/A	N/A	N/A	16.0	–[a]
NO_2-N	Mg/L	0.102	N/A	N/A	N/A	0.102	–[c]
NO_3-N	Mg/L	1.41	N/A	N/A	N/A	1.41	–[c]
NH_3-N	Mg/L	3.75	N/A	N/A	N/A	3.75	–[c]
Org-N	Mg/L	3.50	N/A	N/A	N/A	3.50	–[c]
Total N	Mg/L	8.76	N/A	N/A	N/A	8.76	–[c]
PO_4-P	Mg/L	1.382	N/A	N/A	N/A	1.382	–[c]
Total P	Mg/L	3.11	N/A	N/A	N/A	3.11	–[c]
$CBOD_5$	Mg/L	<10.0	N/A	N/A	N/A	<10.0	–[c]
$NBOD_5$	Mg/L	> 0.0	N/A	N/A	N/A	> 0.0	–[c]
$TBOD_5$	Mg/L	<10.0	N/A	N/A	N/A	<10.0	–[c]
Discharge	Mgd/cfs	N/A	N/A	N/A	N/A	N/A	–[a]

Synoptic Water Quality Survey No. 3—August 6, 1974

Germantown Old Village Plant

Parameter	Units	0510	1110	1710	2345	Average	Total Transport (lbs/day)
Temperature	°F	69.8	73.4	77	73.4	73.4	–[a]
Dissolved Oxygen	Mg/L	8.4	17.2	18.4	18.8	16.7	–[a]
pH	S.U.	8.5	8.6	8.9	9.0	8.75	–[a]
Fecal Coliforms	MFFCC/ 100 ml.	N/A	20	20	<10	<16.7	–[a,b]
Chlorides	Mg/L	90	76	71	71	77	411
Conductivity	MM/cm	898	886	890	887	890.75	–[a]
Turbidity	Mg/L	5.4	3.4	2.3	5.5	4.15	–[a]
NO_2-N	Mg/L	0.206	0.219	0.205	0.214	0.211	1
NO_3-N	Mg/L	3.140	2.650	2.850	2.570	2.802	15
NH_3-N	Mg/L	1.700	1.560	1.540	1.390	1.572	8
Org-N	Mg/L	1.870	2.80	2.14	1.86	2.17	12
Total N	Mg/L	6.997	7.226	6.757	6.022	6.75	36
PO_4-P	Mg/L	2.448	1.443	1.561	1.413	1.716	9
Total P	Mg/L	2.75	1.64	1.44	1.27	1.75	9
$CBOD_5$	Mg/L	6.0	4.0	7.0	7.5	6.1	33
$NBOD_5$	Mg/L	5.0	6.0	8.0	4.5	5.9	31
$TBOD_5$	Mg/L	11.0	10.0	15.0	12.0	12.0	64
Discharge	Mgd/cfs	0.48 / 0.74	0.76 / 1.18	0.69 / 1.07	0.62 / 0.96	0.64 / 0.99	a

Germantown County Line Plant

Parameter	Units	Time					Total Transport (lbs/day)
Temperature	°F	-	-	-	-	-	-
Dissolved Oxygen	Mg/L	-	-	-	-	-	-
pH	S.U.	-	-	-	-	-	-
Fecal Coliforms	MFFCC/ 100 ml.	-	-	-	-	-	-
Chlorides	Mg/L	-	-	-	-	-	-
Conductivity	MM/cm	-	-	-	-	-	-
Turbidity	Mg/L	-	-	-	-	-	-
NO_2-N	Mg/L	-	-	-	-	-	-
NO_3-N	Mg/L	-	-	-	-	-	-
NH_3-N	Mg/L	-	-	-	-	-	-
Org-N	Mg/L	-	-	-	-	-	-
Total N	Mg/L	-	-	-	-	-	-
PO_4-P	Mg/L	-	-	-	-	-	-
Total P	Mg/L	-	-	-	-	-	-
$CBOD_5$	Mg/L	-	-	-	-	-	-
$NBOD_5$	Mg/L	-	-	-	-	-	-
$TBOD_5$	Mg/L	-	-	-	-	-	-
Discharge	Mgd/cfs	-	-	-	-	-	-

Menomonee Falls Pilgrim Road Plant

Parameter	Units	0530	1130	1725	2305	Average	Total Transport (lbs/day)
Temperature	°F	69.8	69.8	71.6	69.8	70.25	–[a]
Dissolved Oxygen	Mg/L	21.0	8.0	7.0	6.8	10.7	–[a]
pH	S.U.	7.4	7.6	7.6	7.4	7.5	–[a]
Fecal Coliforms	MFFCC/ 100 ml.	–[b]	b	–[b]	–[b]	–[b]	–[a,b]
Chlorides	Mg/L	192	443	221	163	255	2,914
Conductivity	MM/cm	1,447	2,209	1,494	1,388	1,629	–[a]
Turbidity	Mg/L	6.6	25.0	18.0	9.2	14.2	–[a]
NO_2-N	Mg/L	0.290	0.498	0.444	0.359	0.398	5
NO_3-N	Mg/L	8.850	8.850	8.640	7.380	8.406	96
NH_3-N	Mg/L	3.940	7.080	5.000	4.980	5.245	60
Org-N	Mg/L	3.08	3.46	3.44	3.54	3.38	39
Total N	Mg/L	16.157	19.875	17.425	16.239	17.424	199
PO_4-P	Mg/L	3.538	1.517	1.458	2.107	2.155	25
Total P	Mg/L	3.99	2.92	2.15	3.32	3.095	35
$CBOD_5$	Mg/L	10.4	11.0	9.0	2.0	8.1	92
$NBOD_5$	Mg/L	8.6	10.0	13.0	17.0	12.2	139
$TBOD_5$	Mg/L	19.0	21.0	22.0	19.0	20.3	232
Discharge	Mgd/cfs	N/A	N/A	N/A	N/A	1.37[f] / 2.12	–[a]

Menomonee Falls Lilly Road Plant

Parameter	Units	0640	1145	1740	2320	Average	Total Transport (lbs/day)
Temperature	°F	71.6	71.6	73.4	71.6	72.05	–[a]
Dissolved Oxygen	Mg/L	19.4	22.2	24.3	19.0	21.22	–[a]
pH	S.U.	8.8	9.2	9.1	9.0	9.02	–[a]
Fecal Coliforms	MFFCC/ 100 ml.	<10	10	40	<10	<17.5	–[a]
Chlorides	Mg/L	366	380	385	371	376	3,136
Conductivity	MM/cm	1,978	1,953	1,926	1,974	1,958	–[a]
Turbidity	Mg/L	6.8	8.7	6.7	8.2	6.8	–[a]
NO_2-N	Mg/L	0.341	0.343	0.372	0.341	0.349	3
NO_3-N	Mg/L	0.980	1.480	1.040	1.390	1.22	10
NH_3-N	Mg/L	7.760	7.440	6.830	7.870	7.475	62
Org-N	Mg/L	4.86	4.92	5.37	5.37	5.13	43
Total N	Mg/L	13.945	14.187	13.609	14.782	14.178	118
PO_4-P	Mg/L	1.399	1.648	1.207	1.62	1.44	12
Total P	Mg/L	2.18	2.55	2.10	2.21	2.26	19
$CBOD_5$	Mg/L	1.0	4.0	6.0	4.0	3.8	32
$NBOD_5$	Mg/L	11.0	11.0	11.0	14.0	11.8	98
$TBOD_5$	Mg/L	12.0	15.0	17.0	18.0	15.5	129
Discharge	Mgd/cfs	N/A	N/A	N/A	N/A	1.00[f] / 1.55	–[a]

Butler Bypass and Chlorination Facility

Parameter	Units	0810	1205	1755	2340	Average	Total Transport (lbs/day)
Temperature	°F	62.6	66.2	68.2	64.4	64.85	–[a]
Dissolved Oxygen	Mg/L	4.6	4.2	10.0	2.8	5.38	–[a]
pH	S.U.	7.4	7.4	6.8	6.8	7.1	–[a]
Fecal Coliforms	MFFCC/ 100 ml.	–[b]	–[b]	–[b]	–[b]	–[b]	–[a,b]
Chlorides	Mg/L	728	231	119	95	293	–[c]
Conductivity	MM/cm	2,936	1,700	1,615	1,315	1,841.5	–[a]
Turbidity	Mg/L	27.0	42.0	27.0	38.0	33.5	–[a]
NO_2-N	Mg/L	0.165	0.152	0.171	0.207	0.174	–[c]
NO_3-N	Mg/L	0.820	0.220	0.820	0.770	0.658	–[c]
NH_3-N	Mg/L	8.010	17.89	20.81	18.55	16.26	–[c]
Org-N	Mg/L	19.70	10.26	19.70	13.82	15.87	–[c]
Total N	Mg/L	28.696	28.519	41.30	33.348	32.965	–[c]
PO_4-P	Mg/L	2.239	3.965	13.464	9.806	7.368	–[c]
Total P	Mg/L	5.17	6.94	19.70	15.02	11.70	–[c]
$CBOD_5$	Mg/L	> 100.0	> 100.0	>100.0	>100.0	>100.0	–[c]
$NBOD_5$	Mg/L	> 50.0	> 50.0	> 50.0	> 50.0	> 50.0	–[c]
$TBOD_5$	Mg/L	>150.0	>150.0	>150.0	>150.0	>150.0	–[c]
Discharge	Mgd/cfs	N/A	N/A	N/A	N/A	N/A	–[a]

[a] Not applicable.

[b] Fecal Coliform samples taken from Sewage Treatment Plant Lagoon effluents only.

[c] Discharge data not available for computation of daily transport.

[d] Based on average daily flow metered from 8 a.m. April 4, 1973, to 8 a.m. April 5, 1973.

[e] Based on average daily flow metered from 8 a.m. July 18, 1973, to 8 a.m. July 19, 1973.

[f] Based on average daily flow metered from 8 a.m. August 6, 1974, to 8 a.m. August 7, 1974.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Village of Menomonee Falls Lilly Road Sewage Treatment Plant: As shown on Map 60, this sewage treatment plant is located to the east of the Menomonee River about one mile downstream of the Pilgrim Road plant near Lilly Road. Selected information about this treatment facility, which discharges to the Menomonee River, is set forth in Table 41.

Service Area: As noted above, in 1970 the Lilly Road sewage treatment plant, in conjunction with the Pilgrim Road facility, served about 17,400 persons in a combined area of about 3.8 square miles as shown on Map 12. It should be noted that the Menomonee Falls sewer system can be controlled to divide the flows between the two plants.

Type and Level of Treatment: The Lilly Road plant, an activated sludge type plant with a flow through lagoon for final sedimentation, was constructed in 1969. The average hydraulic design capacity of the plant is 1.0 mgd, with a peak hydraulic design capacity estimated to be 2 mgd. The average hydraulic loading on the plant in 1970 was estimated at 0.7 mgd, indicating that the plant had adequate capacity to treat the average daily flow from its sewer service area. The treatment processes provided at the plant are classified as tertiary level.

Recommendations of the Regional Sanitary Sewerage System Plan and Implementation Status: As noted above, the adopted regional sanitary sewerage system plan recommended the eventual abandonment of both the Village's Lilly Road and Pilgrim Road sewage treatment plants, and the Village is committed by contract to abandon these two facilities as soon as gravity flow trunk sewer capacity is provided at the Milwaukee-Waukesha line by the Milwaukee-Metropolitan Sewerage Commissions. It is anticipated that this trunk sewer will be completed by 1981.

Village of Butler Overflow-Chlorination Facility: This facility, as shown on Map 60, is located on the west bank of the Menomonee River in the City of Milwaukee about 0.1 mile east of the Village of Butler-City of Milwaukee line and discharges to the Menomonee River. Selected information about this treatment facility is set forth in Table 41. Management of the Village of Butler sanitary sewerage system is under the direction of the Village Board. Day-to-day administration of the system is provided by the Water and Sewer Superintendent. Financing of the system is provided through a sewer service charge based upon the quarterly water billings.

The existing service area of the Village of Butler sanitary sewerage system encompasses the entire Village. This area totals about 0.8 square mile and has a resident population of about 2,300 persons. The entire area is served by a separate sanitary sewer system.

The Village of Butler contracts with the Milwaukee-Metropolitan Sewerage Commissions for sewage treatment. The average hydraulic loading on the Milwaukee-Metropolitan sewerage system from the Village of Butler in 1970 was estimated at 0.4 mgd. Pending completion of trunk sewer construction, sewage flow from the Village to the Milwaukee-Metropolitan sewerage system is limited to 400,000 gallons per day. Any flow in excess of this amount is bypassed through a chlorination tank and discharged to the Menomonee River. At the present time it is anticipated that the trunk sewer connection will be completed by 1981 thus facilitating the planned abandonment of the overflow-chlorination facility.

Sanitary Sewerage System Flow Relief Points

In addition to sewage treatment facility effluent, raw sanitary sewage enters the surface water system of the Menomonee River watershed either directly from combined or sanitary sewer overflows or indirectly via separate storm sewer systems. This direct or indirect conveyance of sanitary sewage to the watershed's surface water system occurs as a result of the presence of five types of flow relief devices: combined sewer outfalls, crossovers, bypasses, relief pumping stations, and portable pumping stations.

Flow Relief Devices: Types and Characteristics: A combined sewer is intended to carry sanitary sewage at all times, including domestic, commercial, and industrial wastes. During periods of rainfall or snowmelt, a combined sewer is intended also to carry storm water runoff from streets and other sources. A combined sewer outfall is a point at which a combined sewer discharges directly into a receiving body of surface water.

The four other flow relief features usually found in a municipal sanitary sewerage system—crossovers, bypasses, relief pumping stations and portable pumping stations—are defined as follows:

- Crossover . . . A flow relief device by which sanitary sewers discharge a portion of their flow, by gravity, into storm sewers during periods of sanitary sewer surcharge or by which combined sewers discharge a portion of their flow, by gravity, into storm sewers to alleviate sanitary or combined sewer surcharge.

- Bypass . . . A flow relief device by which sanitary sewers entering a lift station, pumping station, or sewage treatment plant can discharge a portion or all of their flow, by gravity, into a receiving body of surface water to alleviate sewer surcharge. Also, a flow relief device by which intercepting or main sewers can discharge a portion or all of their flow by gravity into a receiving body of surface water to alleviate intercepting or main sewer surcharge.

- Relief Pumping Station . . . A flow relief device by which flows from surcharged main sewers are discharged into storm sewers or directly into a receiving body of surface water through the use of permanent lift or pumping stations.

- Portable Pumping Station . . . A point of flow relief at which flows from surcharged sanitary sewers are discharged into storm sewers or directly into a receiving body of surface water through the use of portable pumping units.

Of the five types of sanitary sewerage system flow relief devices—combined sewer outfall, crossover, bypass, relief pumping station, and portable pumping station—the combined sewer outfall and bypass always discharge directly to surface waters and therefore are located near rivers and streams. Crossovers always convey flow from a sanitary or combined sewer to a storm sewer and, therefore, need not be located near rivers and streams but may be found anywhere in the sewered portions of urban areas. Inasmuch as relief and portable pumping stations convey flow to either storm sewers or directly to surface waters, these two flow relief devices may be found anywhere in the sewered portions of urban areas. The single most important aspect of the aforementioned five flow relief devices is that each provides a mechanism whereby raw sanitary sewage can be directed to the surface waters in the urban areas of a watershed thereby posing a pollution threat in general, and a health hazard in particular.

Number and Location of Flow Relief Devices in the Watershed: As discussed in Chapter X of this volume, a Wisconsin Pollution Discharge Elimination System (WPDES) has been established by the Wisconsin Department of Natural Resources. This operational permit system provided a source of data and information concerning the number, type, and location of the five types of municipal sewer system relief points in the Menomonee River watershed.

Table 43 summarizes by receiving stream and civil division the type and number of flow relief devices in the watershed, whereas the spatial distribution of these devices is shown on Map 61. A total of 25 combined sewer outfalls and 102 other flow relief devices are known to exist in the Menomonee River watershed. Of the total of 127 known municipal sewer system relief devices where raw sanitary sewage or a mixture of raw sanitary sewage and storm water runoff are discharged during periods of sewer surcharge to watershed surface waters, 102 or over three-fourths discharge directly or indirectly to the Menomonee River. About 40 percent of all the flow relief devices in the Menomonee River watershed, including all of the combined sewer overflows, are located within the City of Milwaukee.

The Combined Sewer System—Previous Studies, Recommendations, and Progress Toward Implementation: *The Combined Sewer System:* The 10.7-square mile combined sewer service area, tributary via the 25 combined sewer outfalls to the Menomonee River, is shown on Map 62. As is evident from the map, the Menomonee River watershed combined sewer system is part of a large contiguous combined sewer service area encompassing a total of about 27 square miles and including portions of the City of Milwaukee and the Village of Shorewood in Milwaukee County. During significant rainfall and snowmelt events, this large combined sewer service area discharges combined sewage to the Menomonee, Milwaukee, and Kinnickinnic Rivers and to Lake Michigan.

Table 43

KNOWN COMBINED SEWER OUTFALLS AND OTHER FLOW RELIEF DEVICES IN THE MENOMONEE RIVER WATERSHED BY RECEIVING STREAM AND CIVIL DIVISION: 1975

Receiving Stream	Civil Division	Combined Sewer Outfalls[a]	Other Flow Relief Devices[a] Crossovers	Bypasses	Relief Pumping Stations	Portable Pumping Stations	Total
Menomonee River[b]	City of Milwaukee	25	22	0	0	2	49
	City of Wauwatosa	0	24	0	0	10	34
	Village of Menomonee Falls	0	2	3	4	10	19
Little Menomonee River	City of Milwaukee	0	0	0	0	1	1
Underwood Creek	City of Wauwatosa	0	1	0	0	7	8
	City of Brookfield	0	0	0	0	3	3
Honey Creek	City of Milwaukee	0	0	0	0	2	2
	City of Wauwatosa	0	6	0	0	2	8
	City of West Allis	0	3	0	0	0	3
Total		25	58	3	4	37	127

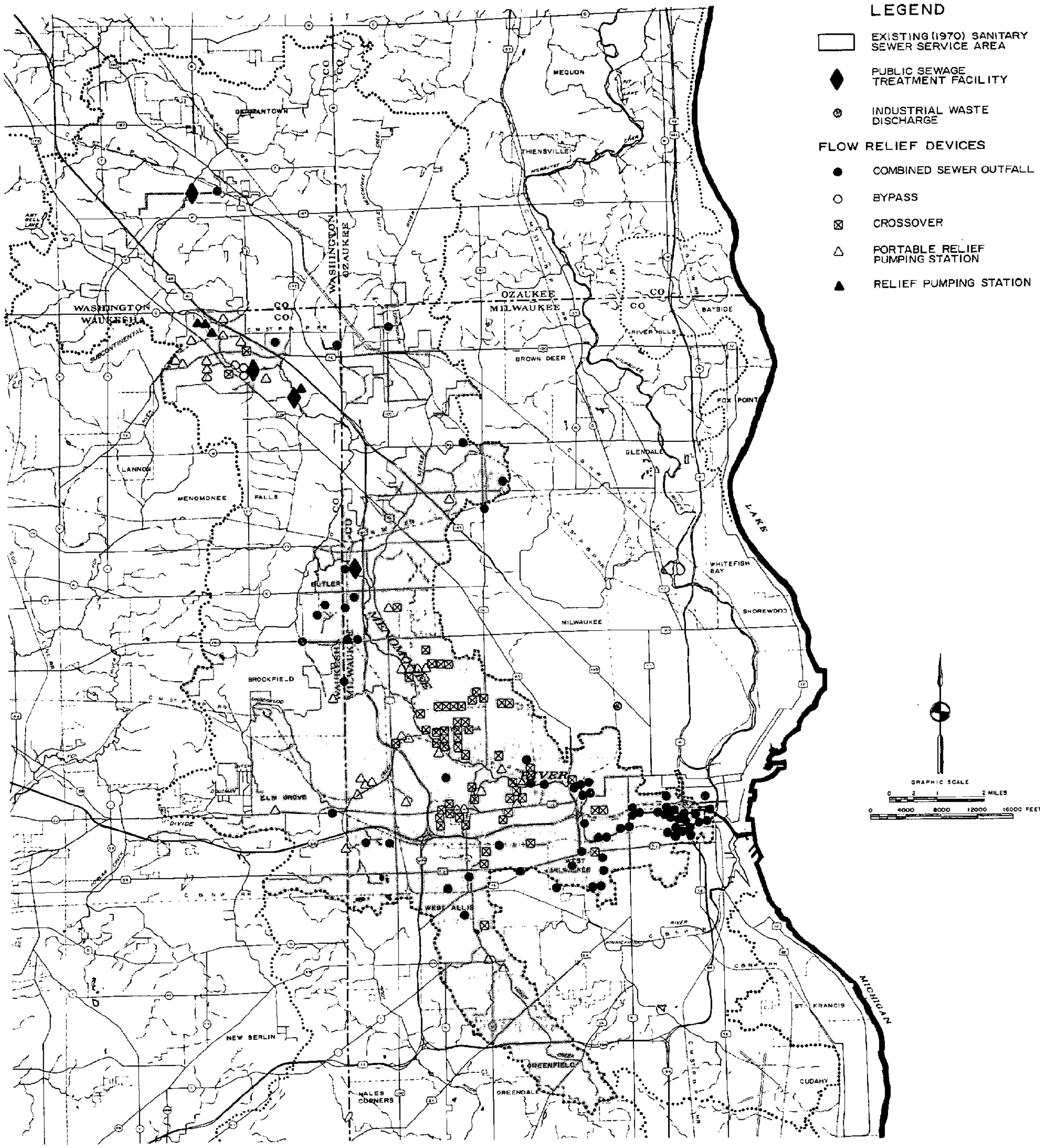
[a] *Based on Wisconsin Pollution Discharge Elimination System permits as of May 1975.*

[b] *Includes South Menomonee Canal which has two combined sewer outfalls and Burnham Canal which has six combined sewer outfalls.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 61

POINT SOURCES OF WATER POLLUTION IN THE MENOMONEE RIVER WATERSHED: 1975

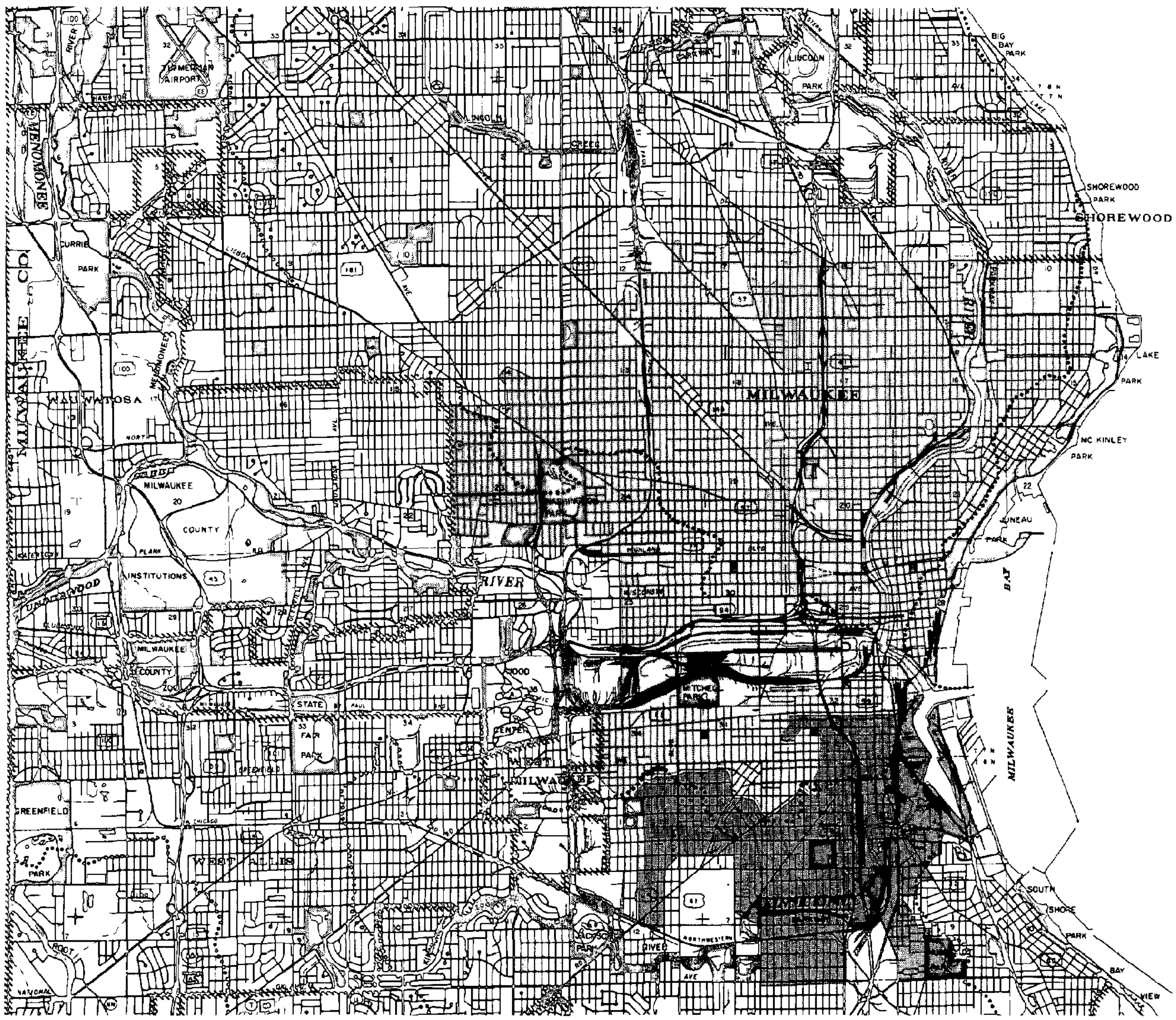


A total of 175 known point sources of pollution existed in the Menomonee River watershed in 1975. These consisted of four municipal sewage treatment facilities; 25 combined sewer outfalls and 102 sanitary sewer overflow relief devices which discharged raw sewage to the River system during periods of wet weather and sewer surcharge; and 44 industrial waste outfalls which discharged primarily cooling and process waters to the River system.

Source: SEWRPC.

Map 62

COMBINED SANITARY AND STORM SEWER SERVICE AREAS IN MILWAUKEE COUNTY: 1970

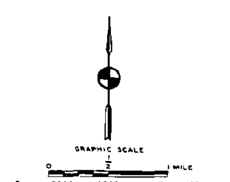


LEGEND

COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MENOMONEE RIVER (6,843 ACRES)

COMBINED SEWER SERVICE AREA TRIBUTARY TO THE KINNICKINNIC RIVER (2,868 ACRES)

COMBINED SEWER SERVICE AREA TRIBUTARY TO THE MILWAUKEE RIVER (5,584 ACRES)



Until the mid-1920's, development in the Milwaukee area was designed to be served by combined sanitary storm sewers which discharged directly to watercourses. About 17,200 acres of the Milwaukee area are still served by these combined sewers. Intercepting sewers have been constructed, however, to intercept the normal dry-weather flow of sanitary wastes in the combined sewers, as well as a portion of the storm flows, and convey these flows to the Jones Island sewage treatment plant. During storm periods excess flows consisting of raw sanitary sewage and storm water, are discharged to watercourses an average of about 50 times per year. A total of 25 combined sewer outfalls, serving a 6,843 acre combined sewer service area tributary to the Menomonee River watershed, discharge directly to the Menomonee River.

Source: Milwaukee-Metropolitan Sewerage Commissions, City Engineer, and SEWRPC.

Findings of the Milwaukee River Watershed Study: The entire Milwaukee metropolitan area combined sewer system was inventoried and analyzed under the Milwaukee River watershed planning program conducted by the Commission, the results of which were published in October 1971. In light of this work, the combined sewer service area in the Menomonee River watershed was not subjected to extensive analysis under the Menomonee River watershed planning program. The principal findings of the Milwaukee River watershed plan as they relate to the combined sewer overflow problem are as follows:

- Until the mid-1920's, no treatment of sanitary sewage was provided in the Milwaukee area, with raw sewage being discharged directly to watercourses. Since that time, and partly as a result of severe outbreaks of typhoid fever within the Milwaukee area, the Milwaukee-Metropolitan Sewerage Commissions have constructed two large sewage treatment plants and an extensive system of main, relief, and intercepting sewers. The intercepting sewers in the combined sewer service area generally parallel the Menomonee, Milwaukee, and Kinnickinnic Rivers.

- During dry weather periods, the sanitary sewage from the combined sewer service area is conveyed via the interceptor sewers to the treatment facilities.

- A mixture of sewage and storm water is discharged to the Milwaukee metropolitan area surface waters through up to about 112 combined sewer outfalls on the average of about 50 times per year as a result of rainfall and snowmelt events producing runoff far in excess of what can be conveyed by the interceptor sewers.

- An analysis of the potential effects of overflows from the 2,100 acre combined sewer service area above the North Avenue dam revealed that such overflows have a frequent, severe, adverse impact on river water quality and that in the presence of such overflows the river is unfit for any type of desirable recreational or fish and aquatic life uses. Similar conclusions may be drawn by inference for other portions of the Milwaukee metropolitan area combined sewer system.

Recommendations of the Milwaukee River Watershed Plan: After a preliminary screening of 15 alternatives and a more detailed study and analysis of three of those 15 alternatives, it was recommended that a combination deep tunnel mined storage/flow-through treatment alternative be included in the comprehensive Milwaukee River watershed plan as the major water pollution abatement plan element for the lower Milwaukee River. It was further recommended that a preliminary engineering study be undertaken to determine with greater precision and detail the configuration of the recommended system as required to serve the entire 27-square-mile combined sewer service area in Milwaukee County.

Progress Toward Implementation: In October 1974, the Milwaukee-Metropolitan Sewerage Commissions, using a federal sewerage facilities planning grant, retained the services of a consulting firm to conduct the above-recommended preliminary engineering study for the abatement of combined sewer overflow in the Milwaukee metropolitan area. This study is scheduled for completion in 1977 and is intended to build on the previous work by the Regional Planning Commission under the Milwaukee River watershed planning program. The study is to provide firm recommendations for construction of sewage conveyance and treatment facilities so as to abate pollution from the entire combined sewer service area. It is important to emphasize that this study includes that portion of the combined sewer service area tributary to the Menomonee River and will culminate in specific recommendations for abatement of the combined sewer overflow problem in the watershed.

Industrial Discharges

In a number of locations in the Menomonee River watershed, industrial wastewater consisting primarily of cooling water and process water is discharged directly or indirectly to the surface water system. This industrial wastewater enters the Menomonee River and its major tributaries as direct discharge or reaches the surface waters via drainage ditches and storm sewers. In a few instances, the wastewater is subject to land disposal and subsequent seepage into the soil. These discharges are of concern primarily because they may contain toxic substances or high concentrations of undissolved solids.

Number and Location of Industrial Discharges: As described in Chapter X of this volume, a Wisconsin Pollution Discharge Elimination System has been established by the Wisconsin Department of Natural Resources. Data and information provided by this system were used to determine the type and location of industrial discharges in the Menomonee River watershed.

Table 44 summarizes by receiving stream and civil division the type and number of industrial discharges in the watershed while their spatial distribution is illustrated on Map 61. A total of 44 industrial discharges is known to exist in the watershed, and of the six types of discharges identified in Table 44—cooling water, wash water, process water, oil-water separator effluent, condensate, and electrostatic precipitation effluent—half of the discharges consist of cooling water. Over three-fourths of the industrial discharges flow directly or indirectly to the Menomonee River with the remainder being discharged to the Little Menomonee River, Underwood Creek, Honey Creek, and to land disposal. Half of the 44 known industrial discharges in the watershed are located in the City of Milwaukee with almost 85 percent being located in the Milwaukee County portion of the watershed.

Quality Characteristics of Industrial Discharges: Very little data are available on the quality of the water discharged from the various industries. As a result of the initiation of the Wisconsin Pollution Discharge Elimination System, a data base of industrial discharges quality will be developed in the next few years. Effluent from two sources of industrial discharges, the S. K. Williams Company and the Milwaukee Road railroad, were monitored during the three synoptic water quality surveys. These data serve to illustrate the variety of constituents typically found in industrial discharges.

S. K. Williams Company: The S. K. Williams Company, which is located in the City of Wauwatosa, provides metal finishing services including electro-plating and polishing using heavy metals such as cadmium, chromium, copper, and nickel. This facility was selected for monitoring because it was a known source of heavy metals. Process waters as well as cooling waters are discharged to the Menomonee River via a storm sewer. Heavy metal concentrations determined for the S. K. Williams Company discharge during the synoptic water quality surveys are set forth in Table 45. Four samples were taken on each day and analyzed for the following seven heavy metals: cadmium, chromium, copper, lead, mercury, nickel, and zinc.

Table 44

KNOWN INDUSTRIAL WASTEWATER DISCHARGES IN THE MENOMONEE RIVER WATERSHED BY RECEIVING STREAM AND CIVIL DIVISION: 1975

Receiving Stream	Civil Division	Type of Discharge[a]						Total
		Cooling Water	Wash Water	Process Water	Oil-Water Separator Effluent	Condensate	Electrostatic Precipitator Effluent	
Menomonee River[b]	City of Milwaukee	10	1	5	1	1	1	19
	City of Wauwatosa	4	1	3	0	0	0	8
	City of West Allis	0	0	1	1	0	0	2
	City of Brookfield	1	0	0	0	0	0	1
	Village of West Milwaukee	1	0	0	0	0	0	1
	Village of Butler	0	0	0	1	0	0	1
	Village of Menomonee Falls	1	0	0	0	0	0	1
	Village of Germantown	1	0	0	0	0	0	1
Little Menomonee River	City of Milwaukee	1	0	0	2	0	0	3
Underwood Creek	City of West Allis	1	0	0	0	0	0	1
	City of Brookfield	1	0	0	0	0	0	1
Honey Creek	City of West Allis	1	0	1	0	0	0	2
Land Disposal	City of West Allis	0	0	0	1	0	0	1
	City of Brookfield	0	0	1	0	0	0	1
	Village of Menomonee Falls	0	0	1	0	0	0	1
Total	--	22	2	12	6	1	1	44

[a] *Based on Wisconsin Pollution Discharge Elimination System permits as of May 1975.*

[b] *Includes South Menomonee Canal.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

The average cadmium concentration for each of the three surveys exceeded by as much as a factor of 10 the maximum 0.03 mg/l recommended for surface waters supporting fish and aquatic life. Average chromium concentrations for each of the three surveys exceeded by as much as four times the maximum concentration of 0.05 mg/l recommended for enhancement of fish and aquatic life. The average lead concentration for each of the three surveys slightly exceeded the maximum level of 0.03 mg/l recommended for propagation of fish and aquatic life.[28] Inasmuch as the recommended limits for cadmium, chromium, and lead were exceeded in the discharge, these heavy metals may, depending on the amount of dilution that occurs, pose a threat to fish and aquatic life in the Menomonee River.

Mercury levels during the three synoptic surveys were well below the maximum concentration of 0.002 mg/l[29] recommended for protection of fish and aquatic life. Water Quality Criteria[30] does not contain specific fish and aquatic life standards for copper, nickel, and zinc but instead recommends that laboratory sensitivity tests be run on critical flora and fauna for each of these metals using, as a medium, samples of the actual receiving water. A series of such sensitivity tests has not been conducted on Menomonee River water and it is unlikely that it will be carried out. Therefore, it is not possible to comment on the probable significance of the observed concentrations of copper, nickel, and zinc in the industrial discharge.

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[28] *Water Quality Criteria, Ecological Research Series, U. S. Environmental Protection Agency, March 1973.*

[29] *Ibid.*

[30] *Ibid.*

Milwaukee Road Maintenance Complex: This facility is located in the Menomonee industrial valley immediately west of the 35th Street viaduct. Effluent from an oil separator, which is discharged directly to the Menomonee River, was sampled for solids and oxygen demanding materials, and the results are presented in Table 46.

The average total solids concentration for each of the three surveys ranged from 355 to 1,590 mg/l which approximates that found in raw domestic sewage. Average observed total biochemical oxygen demands for each of the three surveys ranged from 11.0 to 89.0 mg/l, thereby exceeding that occurring at the Village of Germantown and Village of Menomonee Falls sewage treatment plants.

Diffuse Source Pollution

Definition and Characteristics of Diffuse Source Pollution: This type of pollution, also referred to as non-point source pollution, consists of various discharges of pollutants to the surface waters that cannot be traced to specific discrete point sources. Diffuse source pollution is transported from the rural and urban land areas of a watershed to the surface waters by means of direct runoff from the land and by interflow during and shortly after rainfall or rainfall-snowmelt events. Non-point source pollution also includes pollutants conveyed to the surface waters via groundwater discharge—baseflow—which is the principal source of streamflow between runoff events.

Diffuse source pollution is qualitatively similar in content to point source pollution in that the former, like the latter, can cause toxic, organic, nutrient, pathogenic, sediment, and aesthetic pollution problems. Non-point source pollution is becoming of increased concern in water resources planning and engineering as efforts to abate point source pollution become increasingly successful. The control of diffuse source pollution is the last

Table 45

HEAVY METAL CONCENTRATIONS AND OTHER PARAMETERS IN THE EFFLUENT DISCHARGED FROM THE S. K. WILLIAMS COMPANY DURING THE SYNOPTIC WATER QUALITY SURVEYS

	April 4-5, 1973					July 18-19, 1973					August 6, 1974				
	Time					Time					Time				
Parameter[a]	0630	1200	1810	2355	Average	0620	1210	1730	0010	Average	0620	1215	1805	2355	Average
Cadmium	0.05	0.55	0.52	0.07	0.30	0.05	0.25	0.21	0.09	0.15	0.03	0.50	0.30	0.07	0.23
Chromium	0.18	0.24	0.23	0.15	0.20	0.20	0.30	0.15	0.20	0.21	0.14	0.12	0.06	0.07	0.10
Copper	0.10	0.34	0.18	0.14	0.19	0.05	0.15	0.65	0.20	0.26	0.11	0.50	0.49	0.30	0.35
Lead	0.04	0.03	0.04	0.03	0.04	0.10	0.05	0.02	0.04	0.05	0.04	0.04	0.04	0.04	0.04
Mercury	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Nickel	0.52	1.00	0.83	0.49	0.71	0.50	0.40	1.00	0.30	0.55	1.10	3.00	1.60	1.40	1.78
Zinc	2.10	2.20	2.30	2.10	2.18	2.30	2.10	2.50	2.10	2.25	3.70	2.90	2.40	2.50	2.88
Temperature (°F)	50.0	53.6	51.8	60.8	54.1	62.6	68.0	69.8	68.0	67.1	62.6	68.0	68.0	66.2	66.2
PH (Std. Units)	7.9	8.0	7.8	7.9	7.9	8.6	8.8	8.9	8.9	8.8	7.6	7.8	7.8	7.7	7.7
DO	8.8	9.0	8.8	N/A	8.9	7.8	7.8	7.3	7.4	7.6	9.1	9.0	8.2	8.0	8.6

NOTE: N/A indicates data not available.

[a] *Numbers in the table are indicated as concentrations in mg/l except where otherwise indicated.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 46

SOLIDS, OXYGEN DEMAND, AND OTHER PARAMETERS IN THE EFFLUENT DISCHARGED FROM THE MILWAUKEE ROAD MAINTENANCE YARD OIL SEPARATOR DURING THE SYNOPTIC WATER QUALITY SURVEYS

Parameter[a]	April 4-5, 1973					July 18-19, 1973					August 6-7, 1974				
	Time					Time					Time				
	0705	1215	1830	0020	Average	0650	1245	1800	0030	Average	0650	1240	1830	0020	Average
Undissolved Solids	50	135	95	70	88	15	25	15	20	19	255	135	35	60	121
Undissolved Volatile Solids	35	45	65	45	48	10	15	10	10	11	130	65	20	40	64
Total Volatile Solids	145	120	150	120	134	60	75	70	75	70	290	220	180	210	225
Total Solids	920	470	640	730	690	390	375	355	410	383	1,590	830	1,070	850	1,085
$CBOD_5$	30.0	30.0	40.0	30.0	32.5	10.0	10.0	10.0	14.0	11.0	21.0	3.0	0.0	12.0	9.0
$NBOD_5$	1.0	31.0	26.0	13.0	17.8	1.0	6.0	5.0	7.0	4.8	68.0	35.0	21.0	66.0	47.5
$TBOD_5$	31.0	61.0	66.0	43.0	50.3	11.0	16.0	15.0	21.0	15.8	89.0	38.0	21.0	78.0	56.5
Temperature (°F)	66.2	66.2	77.0	71.6	70.3	62.6	73.4	71.6	71.6	69.8	73.4	77.0	73.4	73.4	74.3
PH (Std. Units)	6.2	9.2	9.1	8.6	8.3	7.7	8.0	7.9	7.9	7.9	9.2	9.6	6.6	9.4	8.7
D.O.	5.6	7.1	5.3	N/A	6.0	5.4	5.4	5.5	4.4	5.2	5.8	7.3	7.3	6.9	6.8

[a] *Numbers in the table are concentrations in mg/l except as indicated.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

step in the two-step process of rejuvenating selected surface waters to render them suitable for full recreational use and maintenance of a healthy fishery.

Diffuse source pollution generally differs from point source in one important respect: the rate at which the former pollution is transported to the surface water is, relative to the latter, highly irregular in that large portions of the overall transport occurs during those short time periods during which rainfall or snowmelt events are occurring. In the dry period after washoff events, potential diffuse source pollutants gradually accumulate on the land surface as a result of man's activities, becoming available for transport to the surface waters during the next runoff event. Accumulation of potential pollutants on the land surface may be traced to a variety of man-related phenomena such as application of de-icing salts and sand, use of fertilizers and pesticides, poor soil and water conservation practices, dry fallout and washout of atmospheric pollution, and gradual wear and disintegration of vehicles, structures, and facilities.

The potential source of diffuse pollution in the Menomonee River watershed is the entire 137 square mile land surface of the basin. The characteristics and impact of that potential pollution cannot be readily determined, however, because of the lack of necessary qualitative and quantitative data for the watershed. The results of analyses of the few available data sources are presented below.

Significance of Diffuse Source Pollution: The above mentioned 1968-1969 eutrophic evaluation of the Menomonee River watershed concentrated on the sources of the nutrient phosphorus transported by the stream system from the basin. A significant finding of the research was that the rate of conveyance of phosphate-phosphorus—which made up over 80-90 percent of the total phosphorus—from the watershed varied markedly and was highly correlated with precipitation amounts. Phosphate-phosphorus transported from the watershed during the study ranged from negligible daily amounts to as high as 27 pounds per day per square mile or about 1.8 tons per day for the entire watershed. An average of about 3.0 pounds of phosphate-phosphorus per day per square mile were conveyed from the watershed to the estuary, or about 1.7 pounds per acre per year.

Only 40 percent of the phosphate-phosphorus leaving the Menomonee River watershed on an annual basis could be traced to sewage treatment plant effluent so that more than half—1.0 pound per acre per year—was attributable to diffuse or other sources such as sanitary sewerage system overflows. During low flow intervals—that is, periods during which surface runoff did not occur—the transport rate of phosphorus from the watershed approximated that discharged to the stream from municipal sewage treatment plants suggesting that much of the diffuse source phosphate enters the surface waters during rainfall and snowmelt runoff events.

Examination of seasonal variability of phosphate transport from the basin revealed above average rates in spring, summer, and winter with below average rates in the fall. It is interesting to note, however, that the highest concentrations were observed in autumn and appear to be attributable to the low streamflow that normally prevailed during that season.

A key conclusion of the 1968-1969 eutrophic evaluation study of the Menomonee River Watershed is that about 60 percent of the phosphate-phosphorus transported from the watershed is attributable to sources other than sewage treatment plants. While these other sources and the amounts of phosphate-phosphorus contributed by each have not been explicitly identified, the sources are likely to be many and varied and to include, but not be limited to: washoff of chemical and other fertilizers applied to agricultural lands and urban area lawns, discharges from sanitary sewerage system flow relief devices, and washout from the atmosphere. It is also important to note, as briefly discussed in the referenced report, that the lower portion of the Menomonee River Watershed is served by the Milwaukee-Metropolitan sewerage system and that the phosphate-phosphorus generated within that service area is, in effect, transported out of the watershed. If that phosphate-phosphorus were instead discharged to the Menomonee River watershed stream system, the referenced report estimates that the percent contribution by sewage treatment plant discharges would increase from 40 percent to about 75 percent.

Selected Characteristics of Diffuse Source Pollution as Revealed by the Synoptic Surveys: Data obtained from the three synoptic water quality surveys conducted under the Menomonee River watershed planning program provide a means of characterizing diffuse source pollution. This is particularly true of nutrients, fecal coliform counts, dissolved oxygen, and carbonaceous and nitrogenous biochemical oxygen data from the four special land use stations.

Nutrients: Table 47 summarized concentrations of total nitrogen and phosphorus in the runoff from an agricultural area, newer and older primarily residential areas with separate sewer systems, and a primarily residential area with a combined sewer system. With the exception of the combined sewer service area, which exhibits erratic behavior, total phosphorus concentrations were highest for Synoptic Survey 1 during which surface runoff was occurring. Total phosphorus concentrations during that survey exceeded the guideline maximum of 0.10 mg/l in flowing streams to prevent nuisance growth of aquatic flora. Under low flow conditions—Synoptic Surveys 2 and 3—the total phosphorus concentrations in runoff from the agricultural and separate sewered residential areas were generally close to or less than the potential nuisance level. Excluding discharge from the combined sewer service area, total nitrogen concentrations ranged from about 0.8 to 9.0 mg/l and had an average value of 3.6 mg/l. These total nitrogen concentrations are high relative to that needed to sustain prolific aquatic plant growth.

Fecal Coliform Counts: Table 48 summarizes fecal coliform counts found in the runoff from four different land uses in the Menomonee River watershed. The highest fecal coliform concentrations occurred in the discharge from the combined sewer irrespective of the associated hydro-meteorologic conditions. These high counts are primarily the result of domestic waste being transported through or washed from the combined sewer. Although the separately sewered residential areas and the agricultural areas exhibited fecal coliform counts that were much lower than those for the combined sewer discharge, some of the values exceeded the maximum count of 400 colonies per 100 ml specified by the Wisconsin Department of Natural Resources for water intended for recreational use.

Dissolved Oxygen: The concentration and percent saturation of dissolved oxygen in discharge from the four different land use areas is set forth in summary form in Table 49. Dissolved oxygen saturation exceeded 85 percent for all samples except those taken at the combined sewer outfall. This suggests that runoff from agricultural and separately sewered urban areas is generally relatively rich in dissolved oxygen irrespective of antecedent and runoff conditions. This stands in contrast with

Table 47

NUTRIENT CONCENTRATIONS IN DISCHARGE FROM VARIOUS LAND USES IN THE MENOMONEE RIVER WATERSHED

Land Use	Station	Synoptic Survey 1[a] April 4, 1973		Synoptic Survey 2[a] July 18, 1973		Synoptic Survey 3[a] August 6, 1974	
		Total N mg/l	Total P mg/l	Total N mg/l	Total P mg/l	Total N mg/l	Total P mg/l
Agricultural	TMn 16	4.09	0.14	2.74	0.11	2.99	0.10
Newer primarily residential area served by separate sewer	TMn 17	2.57	0.12	0.84	0.04	1.14	0.06
Older primarily residential area served by separate sewer	TMn 18	4.21	0.36	8.98	0.06	5.27	0.02
Older primarily residential area served by combined sewer	TMn 19	3.00	0.59	14.33	6.01	2.36	0.09

[a]*Average of four analyses at approximately six hour intervals.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 48

FECAL COLIFORM COUNT IN DISCHARGE FROM VARIOUS LAND USES IN THE MENOMONEE RIVER WATERSHED

Land Use	Station	Synoptic Survey 1[a] April 4, 1973	Synoptic Survey 2[a] July 18, 1973	Synoptic Survey 3[a] August 6, 1974
Agricultural	TMn 16	395	900	1,605
Newer primarily residential area served by separate sewer	TMn 17	68	200	750
Older primarily residential area served by separate sewer	TMn 18	350	200	545
Older primarily residential area served by combined sewer	TMn 19	5,800	3,615,000	2,995

[a] *Average of two analyses at approximately 12 hour intervals. All concentrations are expressed as MFFCC per 100 ml, that is, membrane filter fecal coliform count per 100 ml.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 49

DISSOLVED OXYGEN CONCENTRATION IN DISCHARGE FROM VARIOUS LAND USES IN THE MENOMONEE RIVER WATERSHED

Land Use	Station	Synoptic Survey 1[a] April 4, 1973			Synoptic Survey 2[a] July 18, 1973			Synoptic Survey 3[a] August 6, 1974		
		D.O. mg/l	Temperature °F	Percent Saturation	D.O. mg/l	Temperature °F	Percent Saturation	D.O. mg/l	Temperature °F	Percent Saturation
Agricultural	TMn 16	11.9	40.3	95	7.9	68.3	90	7.8	64.4	85
Newer primarily residential area served by separate sewer	TMn 17	10.8	40.0	85	7.2	76.9	89	8.2	72.8	96
Older primarily residential area served by separate sewer	TMn 18	10.9	42.8	90	9.0	62.8	97	9.2	64.8	100
Older primarily residential area served by combined sewer	TMn 19	9.7	45.3	83	3.8	62.8	40	9.0	57.3	90

[a] *Average of four analyses at approximately six hour intervals.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

instream dissolved oxygen levels which, as demonstrated later in this chapter, exhibit marked spatial and temporal variations.

Carbonaceous and Nitrogenous Biochemical Oxygen Demand: Five-day carbonaceous, nitrogeneous, and total biochemical oxygen demands are set forth in Table 50 for the four different land uses included in the synoptic surveys. The highest $CBOD_5$, $NBOD_5$, and $TBOD_5$ values were found in discharge from the combined sewer service area, thereby reflecting the presence of organic material in domestic sewage—a total average biochemical oxygen demand of 157 mg/l was obtained for the combined sewer outfall during Synoptic Survey 2. The levels of biochemical oxygen demands were relatively similar in the runoff from the two separately sewered areas and the agricultural areas during each survey. For these three land uses, total biochemical oxygen demand ranged from a low of about 2.0-2.6 mg/l during Synoptic Survey 2 to a high of about 8.0-11.0 mg/l during Synoptic Survey 3 with the latter values approximating that in the effluent of a secondary municipal sewage treatment plant. In most cases, the total biochemical oxygen demand in the discharge from the land areas was approximately equally divided between carbonaceous and nitrogeneous components.

Table 50

CARBONACEOUS AND NITROGENOUS BIOCHEMICAL OXYGEN DEMAND IN DISCHARGE FROM VARIOUS LAND USES IN THE MENOMONEE RIVER WATERSHED

Land Use	Station	Synoptic Survey 1[a] April 4, 1973			Synoptic Survey 2[a] July 18, 1973			Synoptic Survey 3[a] August 6, 1974		
		$CBOD_5$	$NBOD_5$	$TBOD_5$	$CBOD_5$	$NBOD_5$	$TBOD_5$	$CBOD_5$	$NBOD_5$	$TBOD_5$
Agricultural	TMn 16	1.3	1.1	2.4	0.6	2.0	2.6	6.5	3.,	10.2
New primarily residential area served by separate sewer	TMn 17	1.5	1.5	3.0	0.8	1.8	2.6	6.8	4.3	11.1
Older primarily residential area served by separate sewer	TMn 18	4.5[b]	4.5[b]	9.0[b]	1.0	1.0	2.0	4.6	3.4	8.0
Older primarily residential area served by combined sewer	TMn 19	5.0[b]	7.5[b]	12.5[b]	67.0	90.5	157.5	6.2	5.8	12.0

[a] *Average of two analyses at approximately 12 hour intervals. All concentrations are expressed in mg/l.*

[b] *Estimated value.*

Source: *Wisconsin Department of Natural Resources and SEWRPC.*

Sediment Erosion and Yield: A total of 29 measurements of suspended sediment concentration and streamflow were available for the Menomonee River at N. 70th Street in Wauwatosa. These consisted of three measurements made by the USGS as part of its routine sampling program, three measurements made during the synoptic water quality surveys, and 23 measurements made during the preliminary phase of the IJC Menomonee River Pilot Watershed Study. These 29 measurements were used as the basis for estimating the average amount of material eroded from the watershed land surface each year and transported as suspended sediment from the basin. Although it was not possible, because of the limited data available, to analyze the amount of this diffuse source pollutant produced by various land use areas in the watershed, it was possible to compute an average yield per unit area of watershed land surface. Inasmuch as suspended sediment data were used in the analysis, 10 percent was added to the watershed yield to account for bedload which consists of the coarser sediments which are transported in contact with the stream bottom, as opposed to the finer sediments which are transported in suspension in the streamflow and are included in suspended sediment samples.

Data Analysis: The data are presented graphically in Figure 58 which consists of a plot of streamflow in cfs per square mile versus sediment transport in tons per day per square mile. The resulting relationship is similar to a "rating curve" in that it depicts the sediment transport capacity of the Menomonee River at Wauwatosa as a function of discharge.

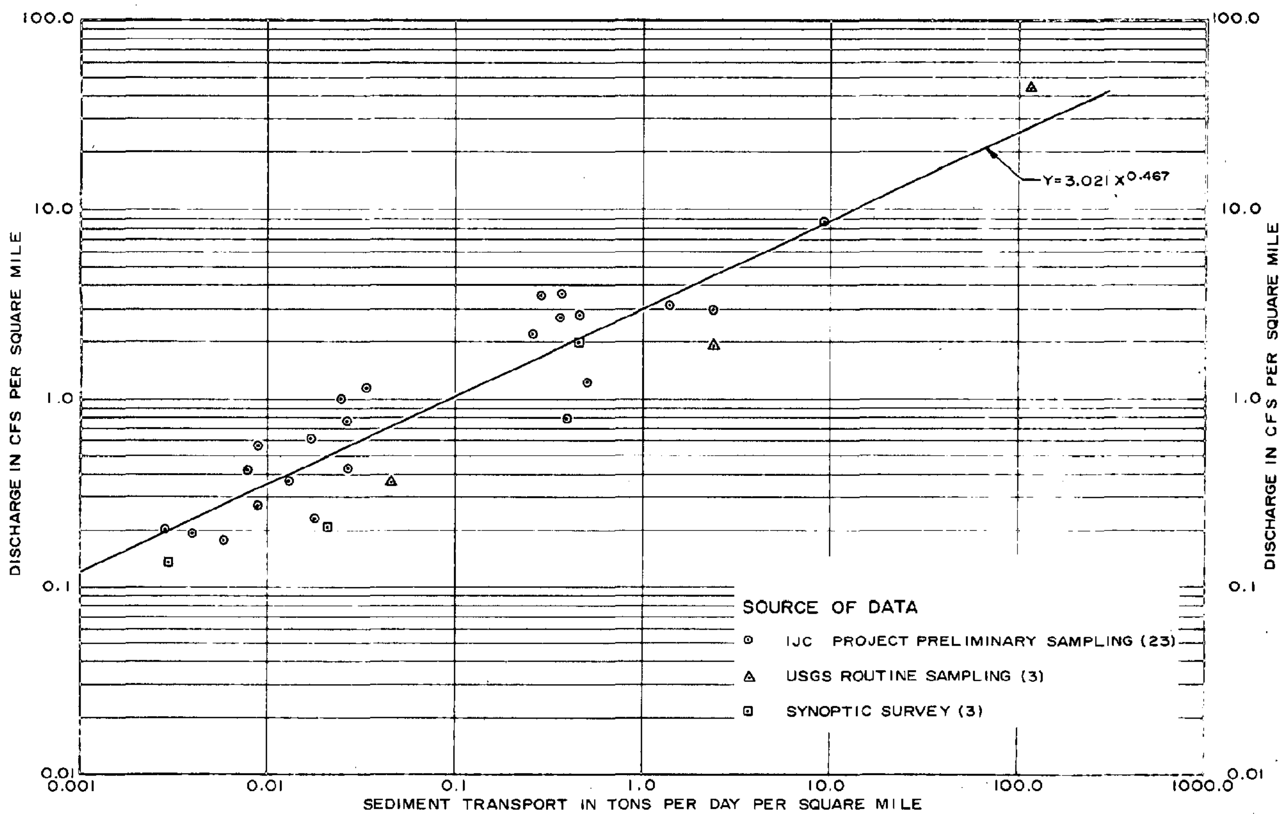
After using the graph to determine the equation relating discharge and sediment yield on the Menomonee River at Wauwatosa, additional data for other locations in the watershed were compared to the data shown on Figure 58. These data were obtained from the three synoptic surveys and consisted of three suspended sediment concentration-streamflow values for each of the following four locations: the Menomonee River at the Washington-Waukesha County line, the Little Menomonee River at Donges Bay Road in Mequon, Underwood Creek near the Menomonee River in Wauwatosa, and Honey Creek near the Menomonee River in Wauwatosa. These 12 additional data points were not used to establish the discharge-suspended sediment yield relations for the Menomonee River watershed because the data were limited in number and because they showed a tendency to exhibit higher sediment yields per unit area for a given discharge per unit area. The latter characteristic is to be expected since the supplemental data are all from areas much smaller than the watershed—the areas tributary to the four supplemental sediment sampling sites vary in size from about 8 to 32 square miles.

The flow duration data for the Menomonee River at N. 70th Street in Wauwatosa were used in conjunction with the above discharge-sediment transport relation, to derive the yearly sediment transport rate for the Menomonee River at that location. Daily discharge rates that occurred during the period October 1, 1961, through September 30, 1973, were divided into classes and the number of days per year in which the flow is likely to be in each class was determined. As set forth in Table 51, the yearly suspended sediment load was calculated by summing the product of days per year that each flow class occurred and the corresponding sediment transport rate as determined from Figure 58.

Results: As shown in Table 51, the suspended sediment load per square mile is estimated as 88.6 tons per year.

Figure 58

RELATIONSHIP BETWEEN SEDIMENT TRANSPORT AND DISCHARGE FOR THE MENOMONEE RIVER AT WAUWATOSA



Source: U. S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

Increasing this value 10 percent to account for the bedload, the total average sediment yield from the watershed at Wauwatosa is estimated at 97.5 tons per square mile per year.

A recent study[31] by the USGS determined average annual suspended sediment yield for streams throughout Wisconsin. The reported average yields, which exclude bedload, varied widely ranging from 5 to 700 tons per square mile per year. Northern, forested areas of the State exhibited the lowest yields while the highest yields of suspended sediment were observed in the "driftless area" of southwestern Wisconsin. The report indicates that high sediment yields are to be expected in urban areas because of such factors as the increased amount of surface runoff, channel modifications, and construction activity. The reported average suspended sediment yield for the seven-county Southeastern Wisconsin Planning Region was about 40 tons per square mile per year.

[31] *S. M. Hindall and R. F. Flint, "Sediment Yields of Wisconsin Streams," Hydrologic Investigations Atlas HA-376, U. S. Geological Survey, Washington, 1970.*

Considering the urbanizing nature of the Menomonee River watershed and noting that the above sediment yield estimates exclude bedload, the value of 97.5 tons per square mile per year obtained for the Menomonee River watershed was considered consistent with the USGS results.

Sediment analyses were conducted under the Commission's Milwaukee River watershed planning program with the conclusion that sediment yield, including an allowance for bedload, approximated about 61 tons per square mile per year for this 694-square-mile primarily rural basin. Considering the urbanizing nature of the Menomonee River watershed and its smaller size relative to the Milwaukee River watershed, the 97.5 tons per square mile per year total sediment yield obtained for the Menomonee River watershed is consistent with the 61 tons per square mile per year yield determined earlier for the Milwaukee River watershed.

Implications: The potential adverse effect of sediment on surface water quality was discussed earlier in this chapter. Inasmuch as the sediment yield of the Menomonee River watershed is relatively high, those water quality effects

Table 51

ESTIMATED YEARLY SUSPENDED SEDIMENT LOAD OF THE MENOMONEE RIVER AT WAUWATOSA

Flow Class	Average Flow (CFS)	Days Per Year	Flow Rate Per Unit Area CFS per Square Mile	Menomonee River Sediment Load Rate Tons per Square Mile Per Year
0	--	--	--	--[a]
1	1.40	0.28	0.0114	--[a]
2	3.10	2.56	0.0276	--[a]
3	3.80	2.19	0.0309	--[a]
4	4.65	2.56	0.0378	--[a]
5	5.65	6.57	0.0459	--[a]
6	6.85	9.13	0.0557	--[a]
7	8.30	21.54	0.0675	--[a]
8	10.05	13.14	0.0817	--[a]
9	12.5	26.28	0.102	--[a]
10	15.0	13.87	0.122	0.014
11	18.0	23.73	0.146	0.036
12	22.0	28.11	0.179	0.067
13	27.0	36.14	0.220	0.132
14	33.0	21.17	0.268	0.119
15	40.0	21.90	0.325	0.186
16	49.0	22.63	0.398	0.294
17	59.5	15.33	0.484	0.307
18	72.5	14.24	0.589	0.427
19	88.5	13.87	0.720	0.652
20	108.5	13.51	0.882	0.959
21	130.0	8.40	1.057	0.924
22	160.0	12.41	1.301	2.048
23	195.0	5.84	1.585	1.518
24	235.0	5.48	1.911	2.055
25	290.0	5.11	2.358	2.913
26	350	4.02	2.846	3.618
27	425	4.02	3.455	5.427
28	520	3.29	4.228	6.745
29	630	2.19	5.122	6.789
30	770	2.56	6.260	12.544
31	925	0.73	7.520	5.183
32	1,150	1.10	9.350	12.540
33	1,400	0.73	11.382	13.140
34	1,700	0.37	13.821	9.990
Yearly Total	--	365.0	--	88.627

[a]*Beyond the range of Figure 58.*

Source: U. S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

may be more acutely manifested in this watershed. In addition to strictly water quality problems, the potential exists for localized sediment deposits and resulting localized flooding and accelerated channel meandering. Inadequate erosion control measures, during urban development and public works construction operations may result in siltation, particularly in small tributary streams. Silt bars also can develop in the main stream system because of poor farming and construction practices and because of the erosion of unstable stream banks and reworking of streambed sediments. Such problems usually are transitional and cannot be quantified on the same basis as can the effects of the long-term sediment-carrying capacity of the streams.

Another pragmatic implication of watershed sediment yield is its effect on navigation in the estuary portion of the River. As discussed in Chapter III of this volume, the Menomonee River is navigable by large commercial vessels from its junction with the Milwaukee River to approximately N. 25th Street extended—a distance of about 1.75 miles. The U. S. Army Corps of Engineers periodically dredges a 75-100 foot width of the channel to a depth of 21 feet below Low Water Datum, 557.1 feet above Sea Level Datum or 23.5 feet below City of Milwaukee datum. Recent maintenance dredging was carried out on the Menomonee River in 1957, 1960, 1962, 1964, 1965, 1966, 1967, 1968, and 1969 and is scheduled for 1976.

The frequency, the lineal extent, and the depth of maintenance dredging is primarily a function of the amount of sediment transported by the Menomonee River and its tributaries to the estuary area, the fraction of that sediment that is trapped in the estuary, and the spatial distribution of the trapped sediment. The Corps of Engineers conducts extensive annual soundings of the estuary area. The resulting cross-sections are examined to determine if shoaling—the gradual, localized accumulation of sediment that tends to begin at the upstream end of the estuary and develop in the downstream direction—has proceeded to the point where sedimentation has reduced the water depth to less than that required for navigation in which case dredging operations are conducted.[32] The 1967, 1968, and 1969 dredging operations in the Menomonee River estuary resulted in the removal of 33,500, 65,600, and 44,500 cubic yards, respectively, of material from the bottom of the navigation channel, or an average of 47,900 cubic yards per year. These are "in place" volumes inasmuch as they are determined by comparing soundings taken before and after the dredging operation.

At an average annual total sediment yield of 97.5 tons per square mile, approximately 13,380 tons of sediment will be delivered annually to the harbor area from the 137-square-mile Menomonee River watershed. Assuming that essentially all of this settles out in the Menomonee River estuary and that the sediment consists primarily of clay and silt with a submerged dry weight of the 40 pounds per cubic foot, the settled sediment would occupy a total volume of about 24,800 cubic yards. If this were spread uniformly over the bottom of the maintained navigation channel—1.75 miles long and 75-100 feet wide—the sediment would accumulate at a rate of about 10 inches per year.

The estimated long-term average annual sediment delivery to the Menomonee River estuary of 24,800 cubic yards is reasonably consistent with the average of 47,900 cubic yards of sediment dredged annually from the estuary during the 1967-1969 period. The difference between the estimated sediment transport volume and the actual dredging volume may be attributable to several factors including limitations inherent in the procedure used to compute the annual volume of sediment accumulation in the estuary and the degree to which the 1967-1969 dredging quantities are representative of long-term volumes.

Land Management Measures on Agricultural Lands: An examination of aerial photographs and a field reconnaissance indicate almost complete absence of land management measures on agricultural lands in the upper Menomonee River watershed. More specifically, basic, low cost agricultural land management techniques such as contour plowing and strip cropping are used very little in the Menomonee River watershed in spite of the fact that the agricultural portions of the basin exhibit considerable relief and steep slopes. The above conclusions concerning the lack of basic land management practices on agricultural lands in the Menomonee River watershed is substantiated by the results of a 1976 Commission inventory of conservation practices funded by the Agricultural Stabilization and Conservation Service, U. S. Department of Agriculture, in the Menomonee River watershed over approximately the past decade. Such conservation measures have been applied to a total of less than one-half square mile, or less than 1 percent, of the agricultural land in the Menomonee River watershed over that period. Therefore, in spite of the availability of technical and financial support from the federal government for application of conservation and land management measures to agricultural lands, voluntary efforts have achieved little in the implementation of such measures in the Menomonee River watershed. It is likely that the organic, nutrient, pathogenic, sediment, and aesthetic pollution present in the surface waters of the upper Menomonee River watershed is due in part to runoff from the agricultural land.

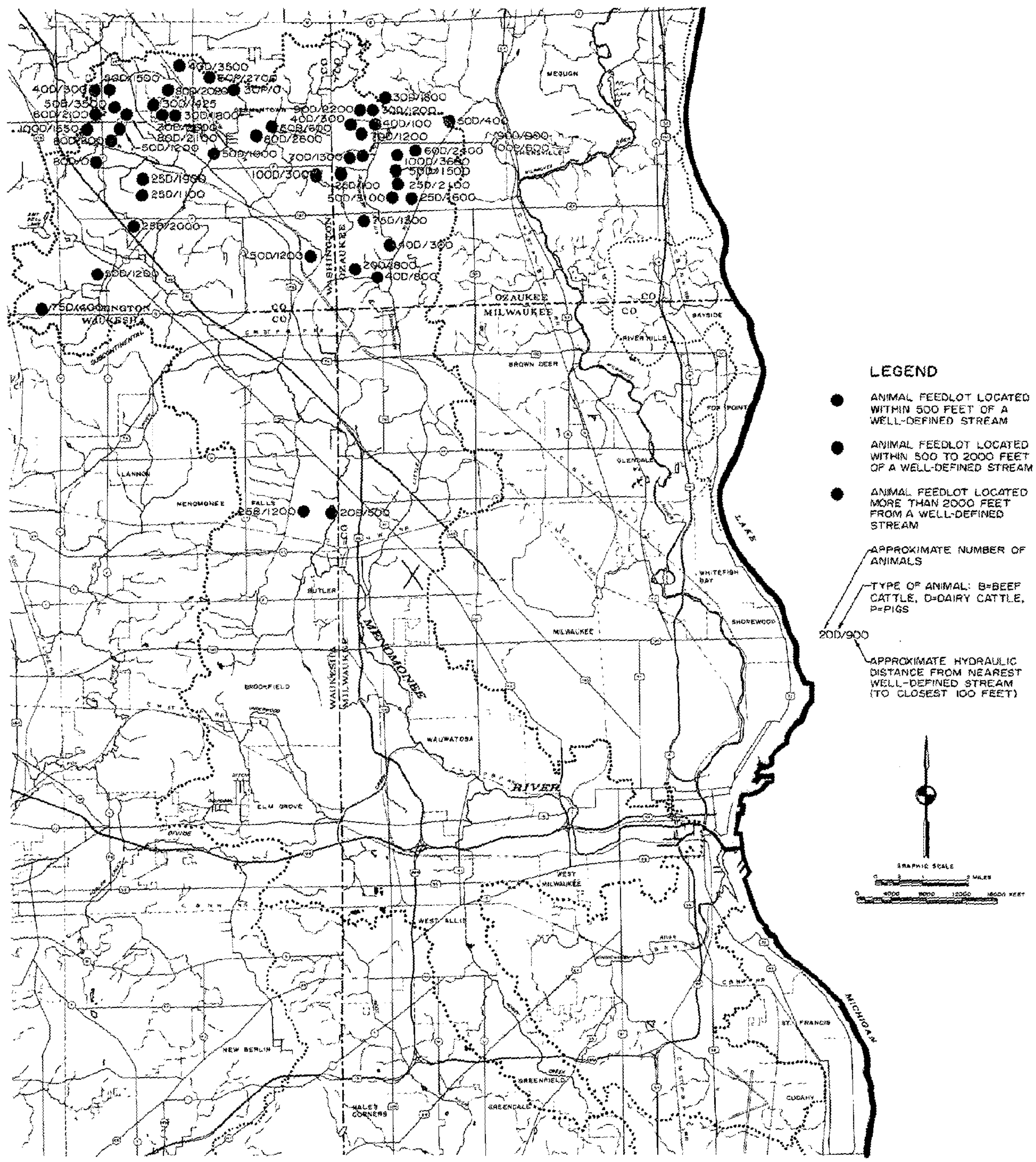
Animal Feedlots: A 1976 inventory revealed in the Menomonee River watershed a total of 49 animal operations with a total of about 2,600 animals representing 42 dairy cattle operations, four beef cattle operations, and three hog operations. These estimates of the number of animal operations as well as the total number of dairy cattle, beef cattle, and pigs are conservative inasmuch as the inventory conducted to obtain the data considered only animal operations of 20 head or larger.

Map 63 shows the locations of the 49 animal operations, the type of animals, and the number involved in each operation, and the approximate hydraulic distance from the nearest well-defined stream to the feedlot. A well-defined watercourse is defined as a natural stream or an artificially constructed channel that usually contains water and is clearly evident on a 1" = 400' scale aerial photograph. Twelve of the barnyards or feedlots, or 25 percent of the total, have hydraulic distance from the nearest well-defined stream of 500 feet or less; 17 barnyards or feedlots, or 35 percent of the total, are within 1,000 feet; and 36 barnyards or feedlots, or about three-fourths of the total, are within 2,000 feet or less. Few, if any, of the barnyards or feedlots have been provided with effective facilities to control runoff from the feedlots or to handle and properly dispose of the solid and liquid waste that accumulates there. Water

[32] *This procedure was interrupted after the 1969 estuary dredging pending completion of outer harbor containment areas for disposal of the dredged material. Prior to this, dredged material was disposed of in the deep waters of Lake Michigan.*

Map 63

ANIMAL FEEDLOTS IN THE MENOMONEE RIVER WATERSHED: 1976



A 1976 inventory revealed a total of 49 animal feedlot operations with a total of about 2,600 animals in the watershed, consisting of 42 dairy cattle operations, four beef cattle operations, and three hog operations. As indicated by the map, about one-fourth of these feedlots are located within 500 feet of a well-defined stream. Few, if any, of the feedlots have been provided with systems to control pollutant washoff from the solid and liquid wastes that accumulate there. Water quality monitoring reveals high fecal coliform counts and phosphorus concentrations, low dissolved oxygen levels, and aesthetic problems in the form of heavy growths of algae and aquatic plants in the surface waters in the headwater portions of the watershed. Some of these conditions must be attributable to feedlot runoff.

Source: SEWRPC.

quality monitoring, as described earlier in this chapter, reveals high fecal coliform counts and phosphate concentration in the headwater portions of the watershed along with low dissolved oxygen levels, all of which must be in part attributable to feedlot runoff. In addition, the feedlot runoff is probably responsible for the aesthetic problems that exist in the form of odor and heavy growths of algae and aquatic plants in and near the creeks and streams receiving runoff from the animal operations.

SURFACE WATER QUALITY AND POLLUTION

As discussed in the preceding section of this chapter, a variety of point and diffuse pollution sources exists within the Menomonee River watershed and discharges potential pollutants to the stream system. Point sources in the watershed include four municipal sewage treatment facilities, 127 sanitary sewerage system flow relief points including 25 combined sewer overflows, and 44 known industrial discharges. In addition, potential diffuse source pollution enters the watershed stream system from the entire 137-square-mile area of the watershed. Pollutants from point and diffuse sources may cause inorganic, organic, nutrient, pathogenic, thermal, and aesthetic pollution. The practical effect of these forms of pollution, whether they occur singly or in combinations, is to restrict or prevent the use of the watershed's stream system for recreational pursuits and propagation of fish and aquatic life.

The purpose of this section of the chapter is to use the available water quality data presented earlier in this chapter to characterize the historic and existing stream water quality conditions in the Menomonee River watershed and to identify the apparent causes of pollution problems. An understanding of the nature and cause of surface water pollution is basic to developing alternative plan elements designed to abate the pollution and thereby lead to the achievement of established water quality objectives.

Findings of the Wisconsin Department of Natural Resources Surveys

1951 Survey: Based on the type and concentration of organisms found in benthic samples, the 1951 basin survey report characterized the Menomonee River upstream of the Old Village area of Germantown as semipolluted, noting that "the bottom community was composed primarily of sludge worms and debris consuming leeches." The problem was attributed primarily to the Rockfield Canning Company which is no longer in operation. Benthic organisms in the Menomonee River about one mile downstream of the Old Village area were found to be entirely pollution-tolerant in nature. Inasmuch as this survey was conducted prior to the 1956 construction of the Old Village municipal sewage treatment plant, the pollution downstream of the Village was attributed to septic tank effluent reaching the Menomonee River via storm sewers.

1952-1953 Survey: The 1952-1953 basin survey found high coliform counts along the entire length of the Menomonee River within Milwaukee County and low dissolved oxygen concentrations downstream of Hawley Road and attributed these to discharges from the Village of Butler sewage treatment plant, to storm water runoff, and to combined sewer overflows. Samples taken along the Little Menomonee River exhibited low dissolved oxygen conditions which were attributed to the organic load being discharged from the settling and filter facilities at the Moss Tie Company. This discharge was found to consist of petroleum products and other wastes resulting from treatment of poles and railroad ties with creosote and oil to prevent deterioration. Erratic and sometimes high coliform counts and low dissolved oxygen concentrations were found on Underwood Creek and Honey Creek with the Honey Creek pollution being attributed primarily to wastes discharged from State Fair Park.

1962 Survey: The 1962 survey, which included only that portion of the Menomonee River in the vicinity of the Village of Germantown and Menomonee Falls municipal sewage treatment plants, indicated that generally satisfactory dissolved oxygen levels were maintained in the Menomonee River. Nutrient and coliform data were not obtained.

1966-1967 Survey: Benthic fauna data obtained during the 1966-1967 basin survey along the Menomonee River in Washington and Waukesha Counties revealed polluted and semipolluted conditions throughout most of the length of the streams. These undesirable conditions were attributed to cooling water and condensate discharge from the Gehl Guernsey Farms, Inc., milk condensing plant in the Village of Germantown and to discharges from the two Village of Germantown sewage treatment plants and the Village of Menomonee Falls Pilgrim Road sewage treatment plant. Menomonee River water quality data revealed high coliform counts and generally substandard dissolved oxygen levels at sites located downstream of the milk condensing plant and of each of the three above mentioned municipal sewage treatment plants.

1968 Survey: Water quality samples collected and analyzed in 1968 along the Menomonee River in Milwaukee County indicated generally adequate dissolved oxygen levels with the exception of the estuary. Very high coliform counts were found to occur all along the Menomonee River, as well as on the Little Menomonee River, Underwood Creek, and Honey Creek near the confluence of each with the Menomonee River. Benthic organism data revealed the existence of highly polluted or sterile conditions along the Menomonee River in Milwaukee County, a condition attributed in part to discharge from the Village of Butler waste treatment facility. Based on benthic samples, polluted conditions were found along the length of the Little Menomonee River downstream of the Moss American, Incorporated with the problem being attributed primarily to discharge of petroleum products from that facility.

Findings of the SEWRPC 1964-1965 Water Quality Survey

Table 52 is a synopsis of water quality conditions in the Menomonee River watershed as determined by 1964-65

Table 52

WATER QUALITY CONDITIONS IN THE MENOMONEE RIVER WATERSHED: 1964-1965

Menomonee River—Nine Sampling Stations

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (mg/l)	425	100	15	51
Dissolved Solids (mg/l)	1,340	705	435	51
Dissolved Oxygen (mg/l)	18.9	7.6	0	99
Coliform Count (MFCC/100 ml)	1,100,000	52,000	100	99
Temperature (°F)	79	49	32	98

Little Menomonee River—One Sampling Station

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (mg/l)	100	65	30	4
Dissolved Solids (mg/l)	815	675	345	4
Dissolved Oxygen (mg/l)	13.2	7.5	0.2	12
Coliform Count (MFCC/100 ml).	16,000	4,700	400	12
Temperature (°F)	78	49	32	11

Underwood Creek—One Sampling Station

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (mg/l)	340	210	80	4
Dissolved Solids (mg/l)	1,090	880	550	4
Dissolved Oxygen (mg/l)	20.4	12.6	4.2	11
Coliform Count (MFCC/100 ml)	83,000	12,100	100	11
Temperature (°F)	78	49	32	11

Honey Creek—One Sampling Station

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (mg/l)	1,270	370	50	10
Dissolved Solids (mg/l)	2,460	985	375	10
Dissolved Oxygen (mg/l)	15.9	11.9	8.0	11
Coliform Count (MFCC/100 ml)	430,000	62,000	1,000	11
Temperature (°F)	67	42	32	11

Source: SEWRPC Planning Report No. 4, Water Quality and Flow of Streams in Southeastern Wisconsin, November 1966.

sampling at nine stations along the entire length of the Menomonee River and one station each on the Little Menomonee River, Underwood Creek, and Honey Creek near their confluences with the Menomonee River. Survey results for chloride, dissolved oxygen, and coliform bacteria are particularly relevant to this assessment of watershed surface water quality.

Chloride: Chloride concentrations throughout the watershed varied from 15 to 1,270 mg/l with the average values for the Menomonee River, Little Menomonee River, Underwood Creek, and Honey Creek being, respectively, 100, 65, 210, and 370 mg/l. Honey Creek exhibited the largest maximum concentration as well as the highest average concentration. The chloride levels in the watershed, which are very high compared to background levels of 20-50 mg/l in a natural surface water environment, may be attributed to such sources as sewage treatment plant effluent, septic tank system discharge, and runoff containing de-icing salt.

Dissolved Oxygen: Dissolved oxygen levels in the watershed ranged from 0 to 20.4 mg/l with the average values for the Menomonee River, Little Menomonee River, Underwood Creek, and Honey Creek being, respectively, 7.6, 7.5, 12.6, and 11.9 mg/l. Although these dissolved oxygen concentrations are relatively high most of the time, instances of substandard levels occurred for extended periods of time over large portions of the stream system. For example, on a sampling day in July 1964, substandard dissolved oxygen levels occurred along the approximately 19-mile-long reach of the Menomonee River beginning at and extending upstream of its confluence with the Little Menomonee River. The maximum, average, and minimum dissolved oxygen concentrations for eight sampling stations along this reach on that day were, respectively, 2.9, 1.3, and 0 mg/l. This example of substandard oxygen levels was attributed to a combination of effects including sewage treatment plant and septic tank discharges and the flushing of vegetal matter from headwater wetlands during a heavy rainfall that occurred four days before the sampling.

Total Coliform Bacteria: Membrane filter coliform count in colonies per 100 ml varied from 100 to 1,100,000 with the average values for the Menomonee River, Little Menomonee River, Underwood Creek, and Honey Creek being, respectively, 52,000, 4,700, 12,100, and 62,000. The largest maximum value occurred on the Menomonee River, while Honey Creek exhibited the highest average coliform count. Prior to the Wisconsin Department of Natural Resources' 1973 adoption of revised water quality standards, which used membrane filter fecal coliform counts, the Department specified membrane filter total coliform counts as a standard for recreational use of surface waters. Average coliform counts obtained during the 1964-65 survey greatly exceeded the previous standard of 1,000 colonies per 100 ml for whole body contact recreation, and average values for three of the above four streams exceeded the partial body contact recreation standard of 5,000 colonies per 100 ml. High watershedwide coliform counts were attributed partly to inadequate disinfection of effluent from municipal sewage treatment plants, but the occurrence of large concentrations on stream reaches not directly influenced by treatment facilities probably also reflects the impact of combined, separate, and storm sewer discharge in the urban areas as well as surface runoff from rural areas.

Findings of the SEWRPC 1968-1974
Continuing Water Quality Monitoring Program

Detailed water quality data for the seven summer sampling periods are available for inspection at the Commission offices. A summary of summer dissolved oxygen, pH, fecal coliform bacteria, and total phosphorus data for each of the 12 sampling stations is set forth in Table 53. These four indicators were selected for analysis because they can be readily related to established water quality standards. For purposes of this evaluation, a sample-day is defined as a summer day in which one or more water quality determinations were made at one of the 12 sampling sites. The total number of sample-days for each parameter is 84, the product of number of field surveys—7—and number of stations—12.

Dissolved Oxygen: For the watershed as a whole, the level of dissolved oxygen in the stream system dropped below the 5.0 mg/l standard for recreational use and fish and aquatic life use on 61 percent of the sample-days. In addition, the oxygen level dropped below the restricted use minimum of 2.0 mg/l on 20 percent of the days. Substandard oxygen concentrations occurred primarily on the Menomonee River and the Little Menomonee River while the single Underwood Creek station always exhibited oxygen concentrations above the established minimums. The discharge of organic oxygen-consuming material from municipal sewage treatment plants may explain the dominance of low dissolved oxygen levels along much of the Menomonee River. The prevalence of substandard dissolved oxygen conditions at locations not within the influence of municipal sewage treatment plant discharges, such as at the upper end of the main stem, on the Little Menomonee River, and on Honey Creek may be attributable to a variety of factors including very low flows, diffuse sources of organic material, sanitary sewer overflows, diurnal dissolved oxygen fluctuations attributable to the photosynthetic and respiratory activity of aquatic flora, and the discharge of oxygen consuming substances from industrial sources such as Moss American, Inc. on the Little Menomonee River. In summary, the continuing water quality monitoring program of the Commission confirms the periodic existence of substandard dissolved oxygen conditions throughout much of the stream system.

Hydrogen Ion Concentration: As indicated in Table 53, the pH values of the watershed surface water system have generally been within the range of 6.0 to 9.0 standard units prescribed for recreational use, fish and aquatic life use, and restricted use. The pH was outside of this range—slightly above—on only two of the 84 sample days.

Fecal Coliform Bacteria: Fecal coliform counts in excess of 400 colonies per 100 ml—the standard for recreational use—were found on over two-thirds of the sample-days, and all 12 monitoring sites exhibited substandard fecal coliform counts on at least two occasions. Furthermore, fecal coliform counts in excess of 2,000 colonies per 100 ml—the restricted use standard—occurred on 21 of the sample days and all 12 monitoring sites exhibited substandard fecal coliform counts on at least one occasion.[33] The highest observed concentration of fecal

[33] *The use of 400 and 2,000 colonies per 100 ml is an approximation of the Wisconsin Department of Natural Resources water quality standards which specify that, for recreational and fish and aquatic life use, the monthly geometric mean fecal coliform count shall not exceed 400 colonies per 100 ml in more than 10 percent of the samples during any month while for restricted use the monthly geometric mean shall not exceed 2,000 colonies per 100 ml in more than 10 percent of the samples during any month.*

Table 53

SELECTED DATA FROM THE SEWRPC-DNR CONTINUING WATER QUALITY MONITORING PROGRAM: SUMMERS OF 1968-1974

Station		Dissolved Oxygen				pH			
		Days on Which D.O. Was Less than 5.0 mg/l		Days on Which D.O. Was Less than 2.0 mg/l		Days on Which pH Was Less than 6.0 Standard Units		Days on Which pH Was Greater than 9.0 Standard Units	
Stream	Identification Number	Number	Percent of Days on Which Samples Were Taken	Number	Percent of Days on Which Samples Were Taken	Number	Percent of Days on Which Samples Were Taken	Number	Percent of Days on Which Samples Were Taken
Menomonee River	Mn 1	5	71	1	14	0	0	0	0
	Mn 2	5	71	3	43	0	0	1	14
	Mn 3	5	71	2	29	0	0	0	0
	Mn 4	6	86	3	43	0	0	0	0
	Mn 5	7	100	4	57	0	0	0	0
	Mn 6	5	71	1	14	0	0	0	0
	Mn 7a	5	71	0	0	0	0	0	0
	Mn 7b	5	71	0	0	0	0	0	0
	Mn 10	1	14	0	0	0	0	0	0
Little Menomonee River	Mn 7	5	71	3	43	0	0	0	0
Underwood Creek	Mn 8	0	0	0	0	0	0	1	14
Honey Creek	Mn 9	2	29	0	0	0	0	0	0
Total	--	51	--	17	--	0	--	2	--
Percentage of All (84) Sample Days	--	61	--	20	--	0	--	2	--

Station		Fecal Coliform				Total Phosphorus	
		Days on Which F.C. Count Exceeded 400 MFFCC/100 ml		Days on Which F.C. Count Exceeded 2,000 MFFCC/100 ml		Days on Which Total P Exceeded 0.10 mg/l	
Stream	Identification Number	Number	Percent of Days on Which Samples Were Taken	Number	Percent of Days on Which Samples Were Taken	Number	Percent of Days on Which Samples Were Taken
Menomonee River	Mn 1	5	71	1	14	2	29
	Mn 2	6	86	4	57	7	100
	Mn 3	2	29	1	14	7	100
	Mn 4	5	71	2	29	7	100
	Mn 5	3	43	2	29	7	100
	Mn 6	4	57	1	14	7	100
	Mn 7a	4	57	1	14	7	100
	Mn 7b	5	71	2	29	7	100
	Mn 10	7	100	2	29	7	100
Little Menomonee River	Mn 7	3	43	1	14	6	86
Underwood Creek	Mn 8	6	86	2	29	2	29
Honey Creek	Mn 9	7	100	2	29	4	57
Total	--	57	--	21	--	70	--
Percentage of All (84) Sample Days	--	68	--	25	--	83	--

Source: Wisconsin Department of Natural Resources and SEWRPC.

coliform bacteria was about 400,000 colonies per 100 ml which was present at station Mn2 on the Menomonee River at STH 167 in the Village of Germantown in August of 1969. The presence of large numbers of coliform bacteria throughout the watershed surface water system indicates the possible presence of pathogenic organisms. These disease producing organisms may be entering the stream system as a result of overflows and land runoff.

Total Phosphorus: As indicated in Table 53, total phosphorus concentrations in the watershed stream system are generally well above the limit of 0.10 mg/l, which is the recognized level of total phosphorus below which nuisance growths of algae and other aquatic plants are not expected to occur in flowing streams. Excessive total phosphorus levels occurred on 93 percent of the sample days with all stations exhibiting high total phosphorus on at least three of the seven possible sample-days. That the widespread occurrence of excessive total phosphorus concentrations throughout the watershed—that is, high phosphorus—is not limited to stream reaches downstream of municipal sewage treatment plant outfalls is another indication that instream phosphorus may be traced to diffuse sources as well as point sources.

Findings of the 1968-69 Eutrophic Evaluation Study

The 1968-1969 eutrophic study provides instream dissolved phosphate determinations for 15 locations in the watershed on the Menomonee River, Little Menomonee River, Underwood Creek, and Honey Creek. A total of 404 instream dissolved phosphorus samples was taken and analyzed over a 21-month period from April 1968 to December 1969 and is available for quantification of the trophic status of the stream system. A series of special analyses indicated that dissolved phosphate, which was used as the principal indicator in the study, very closely approximated total phosphorus, that is, there was very little insoluble phosphorus present in the surface waters.

Table 54 is a summary of instream dissolved phosphate-phosphorus concentrations for the watershed by season and stream reach. The table also indicates the portion of samples containing dissolved phosphorus in excess of 0.10 mg/l which is the recognized level of total phosphorus below which nusiance growths of algae and other aquatic plants are not expected to occur in flowing streams.

About 92 percent of all the samples collected in the watershed contained excessive dissolved phosphorus. As would be expected, the highest dissolved phosphorus concentrations occurred on that portion of the Menomonee River downstream of the municipal sewage treatment plants where concentrations ranged from 0.03 mg/l to 6.30 mg/l and averaged 1.34 mg/l. The average phosphorus concentrations on the Menomonee River above the sewage treatment plants, on the Little Menomonee River, on Underwood Creek, and on Honey Creek were 0.21, 0.22, 0.24, and 0.63 mg/l, respectively, all of which are above the critical level. Maximum concentrations of these four stream reaches were 0.63, 2.42, 0.84, and 4.87 mg/l, respectively.

The widespread occurrence of excessive phosphorus levels throughout the Menomonee River watershed is consistent with one of the key conclusions of the 1968-69 study: up to 60 percent of the phosphorus transported from the watershed by the Menomonee River may be traced to sources other than municipal sewage treatment plants. The large disparity between observed phosphorus concentrations and the recommended limit of 0.10 mg/l suggests that the committed abandonment of the remaining four municipal sewage treatment plants and the connection of the tributary service areas to the Milwaukee-Metropolitan sewerage system will not, in and of itself, be sufficient to generally reduce phosphorus levels to or below the critical value.

Findings of the 1972 Creosote Study

Based on summer of 1971 field reconnaissance, sampling, and laboratory analysis by the Scientific Committee of Citizens for Menomonee River Restoration, Inc., and by personnel of Limnetics, Inc., creosote was found to exist in the bottom muds of the 3.5 mile reach of the Little Menomonee River extending from the Moss American, Inc., facility at W. Brown Deer Road downstream to a point about 2,000 feet downstream of the Fond du Lac Freeway. The downstream terminus of the reach in which creosote was found to exist coincides with the location at which chemical burns were incurred by a participant in the June 5, 1971, cleanup of the Little Menomonee River. The Moss American facility was positively identified as the source of the creosote. A medical examination of first degree burns on the arms and legs and of abdominal pain incurred by a participant attributed the burns and pain to creosote present in the water and bottom muds.

Partly as a result of the above episode of serious chemical pollution in the Little Menomonee River, a series of remedial actions has been taken by Moss American, Inc. On April 10, 1971, the firm ceased drainage of process wastewater to the stream by directing the wastes to a sanitary sewer. Approximately $75,000 was expended by the company on enlarged and improved pre-treatment and pollution abatement facilities. The old, troublesome lagoons and filters on the plant site were eliminated, sludge deposits were removed, and the area was covered with clean fill.

In June of 1973, Envirex, Inc., of Milwaukee was awarded a contract for $170,000 by the U. S. Environmental Protection Agency to remove creosote from the bottom muds and the banks of the Little Menomonee River. The firm was reasonably successful in restoring an approximately 0.76 mile reach of the stream downstream of the Moss American, Inc., facility.[34] The Envirex report recommended extending a creosote cleanup operation downstream to at least the N. Granville Road bridge at River Mile 3.70, a location 1.3 miles downstream of the reach cleaned during the demonstration project.

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[34] *"Demonstration of Removal and Treatment of Contaminated River Bottom Muds—Phase II," Environmental Sciences Division of Envirex, Inc., EPA Contract 68-03-0182, no date, in press.*

Table 54

SUMMARY OF INSTREAM SOLUBLE PHOSPHORUS IN THE MENOMONEE RIVER WATERSHED: 1968-1969

Location		Number of Sampling Sites	Season: Winter (January, February, and March)					
			Number of Samples	PO_4-P in mg/l[a]			Samples Exceeding 0.10 mg/l[b]	
Stream	Reach			Maximum	Minimum	Average	Number	Percent of Total
Menomonee River	Above sewage treatment plants	1	2	0.06	0.06	0.06	0	0
	Below sewage treatment plants	8	16	1.71	0.03	0.59	15	93.8
Little Menomonee River	Rural area—north of W. Good Hope Road	3	6	0.89	0.02	0.22	3	50
	Urban area—south of W. Good Hope Road	1	2	1.51	0.27	0.89	2	100
Underwood Creek	--	1	2	0.84	0.14	0.49	2	100
Honey Creek	--	1	2	0.74	0.07	0.41	1	50
Total	--	15	30	1.71	0.02	0.48	23	76.7

Location		Number of Sampling Sites	Season: Spring (April, May, and June)					
			Number of Samples	PO_4-P in mg/l[a]			Samples Exceeding 0.10 mg/l[b]	
Stream	Reach			Maximum	Minimum	Average	Number	Percent of Total
Menomonee River	Above sewage treatment plants	1	5	0.63	0.15	0.32	4	100
	Below sewage treatment plants	8	74	3.57	0.09	0.99	73	98.6
Little Menomonee River	Rural area—north of W. Good Hope Road	3	21	0.25	0.01	0.13	16	76.2
	Urban area—south of W. Good Hope Road	1	10	0.35	0.02	0.18	8	80
Underwood Creek	--	1	10	0.31	0.04	0.13	6	60
Honey Creek	--	1	10	0.65	0.10	0.30	10	100
Total	--	15	130	3.57	0.01	0.64	117	90.8

Table 54 (continued)

Location: Stream	Location: Reach	Number of Sampling Sites	Season: Summer (July, August, and September): Number of Samples	PO_4-P in mg/l[a]: Maximum	PO_4-P in mg/l[a]: Minimum	PO_4-P in mg/l[a]: Average	Samples Exceeding 0.10 mg/l[b]: Number	Samples Exceeding 0.10 mg/l[b]: Percent of Total
Menomonee River	Above sewage treatment plants	1	11	0.53	0.13	0.24	11	100
	Below sewage treatment plants	8	82	6.30	0.25	1.68	82	100
Little Menomonee River	Rural area—north of W. Good Hope Road	3	32	2.42	0.05	0.32	30	93.8
	Urban area—south of W. Good Hope Road	1	11	0.34	0.13	0.24	11	100
Underwood Creek	--	1	10	0.57	0.14	0.29	10	100
Honey Creek	--	1	10	4.87	0.19	1.13	10	100
Total	--	15	156	6.30	0.05	1.08	154	98.7

Location: Stream	Location: Reach	Number of Sampling Sites	Season: Fall (October, November, and December): Number of Samples	PO_4-P in mg/l[a]: Maximum	PO_4-P in mg/l[a]: Minimum	PO_4-P in mg/l[a]: Average	Samples Exceeding 0.10 mg/l[b]: Number	Samples Exceeding 0.10 mg/l[b]: Percent of Total
Menomonee River	Above sewage treatment plants	1	6	0.26	0.05	0.12	3	100
	Below sewage treatment plants	8	46	3.69	0.11	1.54	46	100
Little Menomonee River	Rural area—north of W. Good Hope Road	3	18	0.35	0.02	0.12	11	61.1
	Urban area—south of W. Good Hope Road	1	6	0.36	0.17	0.24	6	100
Underwood Creek	--	1	6	0.50	0.07	0.24	5	83.3
Honey Creek	--	1	6	0.89	0.17	0.42	6	100
Total	--	15	88	3.69	0.02	0.90	77	87.5

Table 54 (continued)

Location		Number of Sampling Sites	Season: All Seasons					
			Number of Samples	PO_4-P in mg/l[a]			Samples Exceeding 0.10 mg/l[b]	
Stream	Reach			Maximum	Minimum	Average	Number	Percent of Total
Menomonee River	Above sewage treatment plants	1	24	0.63	0.05	0.21	18	83.3
	Below sewage treatment plants	8	218	6.30	0.03	1.34	216	99.1
Little Menomonee River	Rural area—north of W. Good Hope Road	3	77	2.42	0.01	0.21	60	67.5
	Urban area—south of W. Good Hope Road	1	29	1.51	0.02	0.26	27	93.1
Underwood Creek	–	1	28	0.84	0.04	0.24	23	82.1
Honey Creek	–	1	28	4.87	0.07	0.63	27	100
Total	–	15	404	6.30	0.01	0.85	371	91.8

[a] *Although reported values are PO_4-P, laboratory studies conducted as part of the referenced study indicate that PO_4-P very closely approximated total P.*

[b] *Value below which nuisance growths of algae and other aquatic plants are not expected to occur in flowing streams.*

Source: Adopted by SEWRPC from Zanoni, A., "Eutrophic Evaluation of a Small Multi-Land Use Watershed," U.W. Water Resources Center Technical Report, June 1970.

Findings of the 1973-74 Preliminary Phase of the IJC Menomonee River Watershed Study

Heavy Metals: An evaluation of the concentration and probable significance of heavy metals in the surface waters of the Menomonee River watershed was made on the basis of data from samples taken at two sites on the Menomonee River and one site on the Little Menomonee River during the period extending from February 1973 through March 1974. Table 55 summarizes analyses for the following heavy metals: cadmium, cobalt, copper, lead, mercury, nickel, and zinc. Included in the table are maximum, minimum, and average concentrations for each metal at each of the three stations as well as the number of times that critical concentrations were exceeded.

The indicated average concentrations of all seven heavy metals are relatively low. Average heavy metal concentrations are rather uniform in the watershed in that none of the three stations exhibits concentrations that are markedly higher than the other two stations.

An examination of the raw data reveals that none of the total of 46 cadmium measurements exceeded the maximum of 0.03 mg/l recommended for surface waters supporting fish and aquatic life—the maximum recorded cadmium concentration was 0.012 mg/l. There were no cobalt measurements in excess of the 1.0 mg/l level recommended for surface waters supporting fish and aquatic life with the maximum recorded cobalt concentration being 0.053 mg/l. A total of 21 of the 63 lead observations—33 percent—at the three sites exceeded the maximum level of 0.03 mg/l recommended for propagation of fish and aquatic life. This included 36 percent of the analyses conducted on the Menomonee River at N. 70th Street, 24 percent of the analyses carried out on the Menomonee River at N. 124th Street—the Milwaukee and Waukesha County line, and 40 percent of the analyses conducted on the Little Menomonee River at Villard Avenue extended. None of the 25 measured mercury concentrations at any of the three sampling sites exceeded the maximum concentrations of 0.002 mg/l recommended for protection of fish and aquatic life—the maximum recorded value was 0.0008 mg/l.

The water quality criteria established by the National Academies of Sciences and Engineering[35] do not contain specific fish and aquatic life standards for copper, nickel, and zinc, but instead recommend that laboratory sen-

[35] *Water Quality Criteria, Ecological Research Series, U. S. Environmental Protection Agency, March 1973.*

Table 55

SUMMARY OF INSTREAM HEAVY METAL CONCENTRATIONS IN THE MENOMONEE RIVER WATERSHED: 1973-1974

Heavy Metal	Location: Menomonee River at N. 70th Street					Location: Menomonee River at N. 124th Street				
	Number of Samples	Concentration in mg/l			Comment[a]	Number of Samples	Concentration in mg/l			Comment[a]
		Maximum	Minimum	Average			Maximum	Minimum	Average	
Cadmium	18	0.012	0.0002	0.0029	0 Values in Excess of 0.03 mg/l	14	0.010	0.0002	0.0030	0 Values in Excess of 0.03 mg/l
Cobalt	19	0.04	0.0017	0.015	0 Values in Excess of 1.0 mg/l	18	0.053	0.003	0.015	0 Values in Excess of 1.0 mg/l
Copper	23	0.037	0.005	0.023	--	23	0.03	0.003	0.011	--
Lead	22	0.22	0.005	0.041	8 Values (36 Percent) in Excess of 0.03 mg/l	21	0.82	0.0055	0.074	5 Values (24 Percent) in Excess of 0.03 mg/l
Mercury	8	0.0005	0.0002	0.00033	0 Values in Excess of 0.002 mg/l	9	0.0005	0.0002	0.00027	0 Values in Excess of 0.002 mg/l
Nickel	13	0.03	0.008	0.018	--	14	0.033	0.008	0.016	--
Zinc	22	0.3	0.018	0.08	--	22	0.07	0.014	0.03	--

Heavy Metal	Location: Little Menomonee River at Villard Avenue Extended					All Stations				
	Number of Samples	Concentration in mg/l			Comment[a]	Number of Samples	Concentration in mg/l			Comment[a]
		Maximum	Minimum	Average			Maximum	Minimum	Average	
Cadmium	14	0.009	0.0001	0.0024	0 Values in Excess of 0.03 mg/l	46	0.012	0.0001	0.0028	0 Values in Excess of 0.03 mg/l
Cobalt	17	0.03	0.002	0.0098	0 Values in Excess of 1.0 mg/l	54	0.053	0.017	0.013	0 Values in Excess of 1.0 mg/l
Copper	23	0.03	0.001	0.0093	--	69	0.037	0.001	0.014	--
Lead	20	0.30	0.003	0.049	8 Values (40 Percent) in Excess of 0.03 mg/l	63	0.82	0.003	0.055	21 Values (33 Percent) in Excess of 0.03 mg/l
Mercury	8	0.0008	0.0002	0.00035	0 Values in Excess of 0.002 mg/l	25	0.0008	0.0002	0.00031	0 Values in Excess of 0.002 mg/l
Nickel	11	0.024	0.009	0.014	--	38	0.033	0.008	0.016	--
Zinc	21	0.1	0.003	0.03	--	65	0.3	0.003	0.046	--

[a] *Indicated concentrations are critical levels based on recommendations in Water Quality Criteria, Ecological Research Series, U. S. Environmental Protection Agency, March 1973.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

sitivity tests be run for each of these metals on critical flora and fauna using samples of the receiving water as the test medium. The average and maximum concentrations of copper in the watershed were 0.014 and 0.037 mg/l, respectively; average and maximum concentrations of nickel were 0.016 and 0.033 mg/l, respectively; and average and maximum concentrations of zinc were 0.046 and 0.3 mg/l, respectively. In the absence of the recommended sensitivity tests, it is not possible to evaluate the potential impact of these three metals on fish and aquatic life.

Ammonia Nitrogen: Data from the 1973-74 preliminary phase of the IJC project also were used to assess the levels of ammonia nitrogen in the watershed surface waters which are of interest because of the potential toxic effect of ammonia on fish at concentrations in excess of about 2.5 mg/l expressed as nitrogen. A summary of ammonia nitrogen findings by sampling station is set forth in Table 56.

The 66 observed ammonia nitrogen concentrations for the three stations averaged 0.38 mg/l and ranged from

Table 56

SUMMARY OF INSTREAM AMMONIA CONCENTRATIONS IN THE MENOMONEE RIVER WATERSHED: 1973-1974

Location		Number of Samples	Concentration in mg/l as Nitrogen		
Stream	Site		Maximum	Minimum	Average
Menomonee River	N. 70th Street N. 124th Street	22 22	2.30 1.74	0.04 0.09	0.46 0.53
Little Menomonee River	Villard Avenue Extended	22	0.38	0.01	0.16
Total	-	66	2.30	0.01	0.38

Source: Wisconsin Department of Natural Resources and SEWRPC.

0.01 to 2.30 mg/l. Of the three stations, the Menomonee River N. 124th Street station exhibited the greatest average ammonia nitrogen concentration—0.53 mg/l—followed by the Menomonee River N. 70th Street station which had an average ammonia nitrogen concentration of 0.46 mg/l. Little Menomonee River ammonia levels were significantly lower averaging 0.16 mg/l. The higher Menomonee River values may be attributed to ammonia in the effluent from the Village of Germantown, Village of Butler, and Village of Menomonee Falls sewage treatment plants. As noted earlier in this chapter, ammonia was assumed to be potentially toxic to fish populations under summer streamflow conditions in concentrations in excess of about 2.5 mg/l expressed as ammonia nitrogen. The 1973-74 data for the three locations in the watershed include one summer period, that of June through August of 1973. Ammonia nitrogen values during this period were less than 0.25 mg/l at all three sampling locations. Consideration of summer data, as well as that for other seasons, suggests that ammonia toxicity is not a problem in the watershed.

Findings of the 1973-74 Synoptic Surveys

As noted earlier in this chapter, detailed water quality and discharge data obtained from the three 24-hour synoptic surveys, as carried out in April 4, 1973, July 18, 1973, and August 6, 1974, are set forth in tabular form in Appendices C, D, and E of this volume. From the perspective of determining the characteristics of watershed surface waters quality, the synoptic survey data can be used for four specific purposes: to illustrate temporal—diurnal—water quality changes at a given location, to demonstrate spatial water quality variations along particular streams, to evaluate the level of water quality relative to the standards that support the adopted water use objectives, and to identify the probable sources of pollutants being transported in the stream system.

Maps 64, 65, and 66 graphically depict, for Synoptic Surveys 1, 2, and 3, the watershedwide data obtained for 16 different physical and chemical constituents and also show discharge values. Data obtained for six additional chemical and biological parameters are shown on Maps 67, 68, and 69 for Synoptic Surveys 1, 2, and 3, respectively.

Hydro-Meteorologic Conditions Before and During the Surveys: A meaningful interpretation of the water quality conditions monitored during the three synoptic surveys requires an understanding of the precipitation and streamflow conditions that existed during and immediately before the surveys. For example, during dry, low flow periods, potential pollutants being transported in the watershed stream system may be traced to either point sources, such as municipal sewage treatment plants, or to discharge from the groundwater reserves to the stream system. During wet periods, however, pollutants flowing from point sources may be significantly diluted by high streamflows while materials transported in washoff from the rural and urban land surfaces may become important in explaining probable sources of observed instream pollutants.

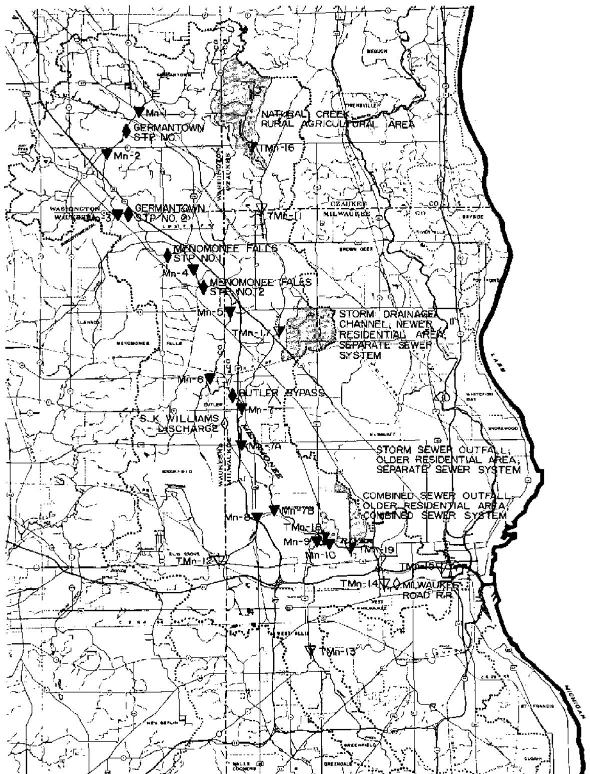
Table 57 summarizes precipitation conditions prior to and during the three synoptic surveys by presenting daily precipitation amounts for the day of the survey as well as the 9 days preceding the survey. Also included in the table is the antecedent precipitation index (API) which is defined for any day as 0.9 times the API of the preceding day plus the precipitation, if any, occurring on the day in question.[36] The API is a measure of the watershed precipitation conditions during and immediately prior to each of the three synoptic surveys with higher values being indicative of wetter conditions.

Table 58 summarizes average streamflows at five locations in the watershed on the day of the survey and also includes daily average flows for six days before the survey at one of the stations—the Menomonee River at Wauwatosa. As shown on Map 60, two of the stations are on the Menomonee River and one each on the Little Menomonee River, Underwood Creek, and Honey Creek. In order to provide a bench mark against which the watershed streamflow could be measured, the flow duration relationship developed for the Menomonee River gage at Wauwatosa was used to determine, for each survey, the percent of days in a year on which the average flow during the survey would be reached or exceeded.

[36] *R. K. Linsley, M. A. Kohler, and Paulhus; Hydrology for Engineers, McGraw-Hill, New York, 1975, pp. 265-266.*

Map 64

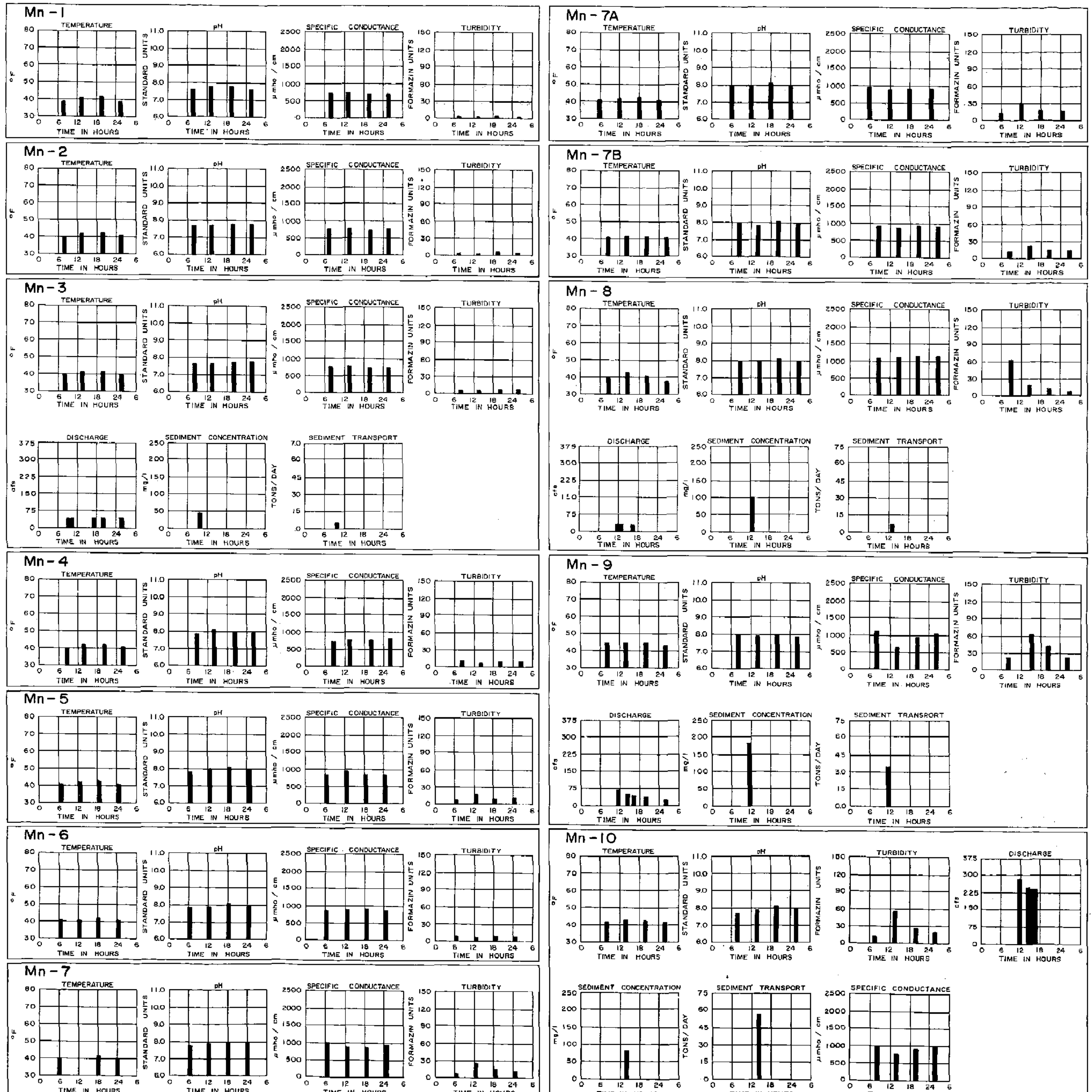
PHYSICAL WATER QUALITY INDICATORS IN THE MENOMONEE RIVER WATERSHED ON APRIL 4, 1973



LEGEND

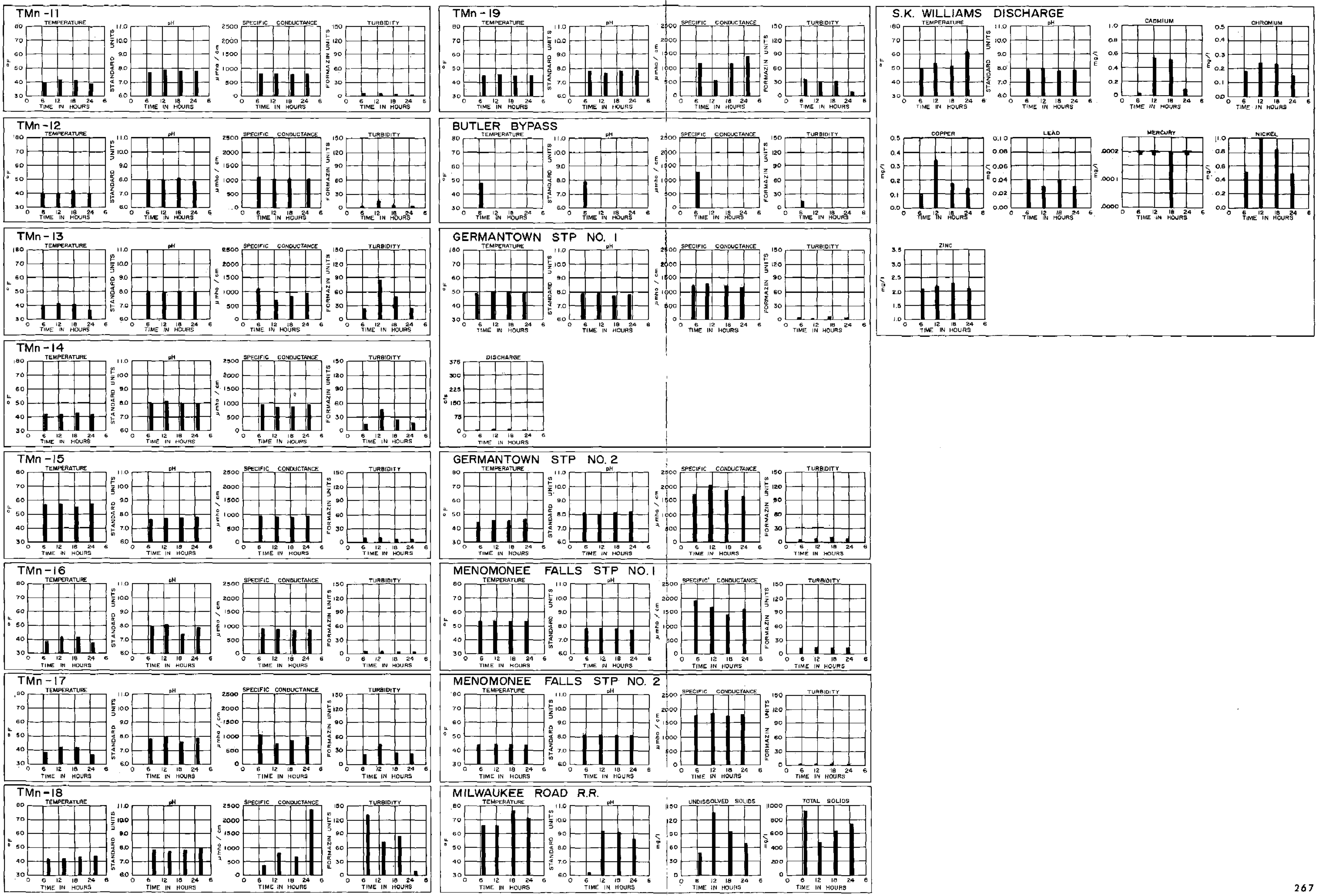
WATER QUALITY SAMPLING STATIONS

- ▼ INSTREAM STATION IDENTICAL TO THOSE USED IN SEWRPC AND SEWRPC-DNR WATER QUALITY MONITORING PROGRAMS (12)
- ▽ INSTREAM STATION TEMPORARILY ESTABLISHED FOR THE WATERSHED STUDY (5)
- ◆ MUNICIPAL SEWAGE TREATMENT PLANT EFFLUENT STATION INCLUDES ALL MUNICIPAL SEWAGE TREATMENT FACILITIES DISCHARGING WITHIN THE WATERSHED (5)
- ◇ INDUSTRIAL WASTEWATER DISCHARGE STATION. INCLUDES POTENTIALLY SIGNIFICANT DISCHARGES (2)
- SAMPLING STATION REPRESENTATIVE OF DIFFERENT WATERSHED LAND USES (4)
- ▭ LAND AREA TRIBUTARY TO STATIONS TMn-16, TMn-17, TMn-18 AND TMn-19
- LESS THAN OR EQUAL TO INDICATED VALUE



The above map shows the quality of the stream waters of the Menomonee River watershed on April 4, 1973, as determined by selected water quality indicators. Up to four analyses were completed at each of 28 sampling locations on April 4, 1973, thus defining temporal and spatial variations in water quality as well as absolute values for comparison to established standards. Instream water temperatures did not exhibit any significant temporal changes and were also spatially uniform throughout the watershed except for the estuary station at which temperatures were about 15°F higher than at the other instream stations. The latter phenomena may be the result of cooling water discharge by the Wisconsin Electric Power Company into the South Menomonee Canal from which some of the heated water may move upstream into the Menomonee River estuary, depending on wind and current conditions. The Wisconsin Department of Natural Resources has established standards for temperature and pH and these standards were satisfied during the April 4, 1973 survey.

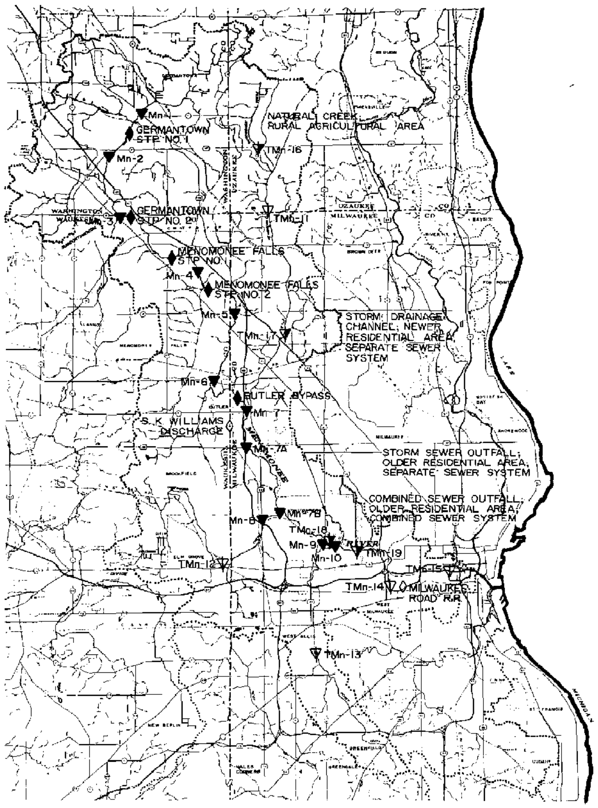
Source: Wisconsin Department of Natural Resources and SEWRPC.



TMn - 11
TMn - 12
TMn - 13
TMn - 14
TMn - 15
TMn - 16
TMn - 17
TMn - 18
TMn - 19
BUTLER BYPASS
GERMANTOWN STP NO. 1
GERMANTOWN STP NO. 2
MENOMONEE FALLS STP NO. 1
MENOMONEE FALLS STP NO. 2
MILWAUKEE ROAD R.R.
S.K. WILLIAMS DISCHARGE
TEMPERATURE
pH
SPECIFIC CONDUCTANCE
TURBIDITY
DISCHARGE
UNDISSOLVED SOLIDS
TOTAL SOLIDS
CADMIUM
CHROMIUM
COPPER
LEAD
MERCURY
NICKEL
ZINC
°F
STANDARD UNITS
µmho / cm
FORMAZIN UNITS
cfs
mg/l
TIME IN HOURS

Map 65

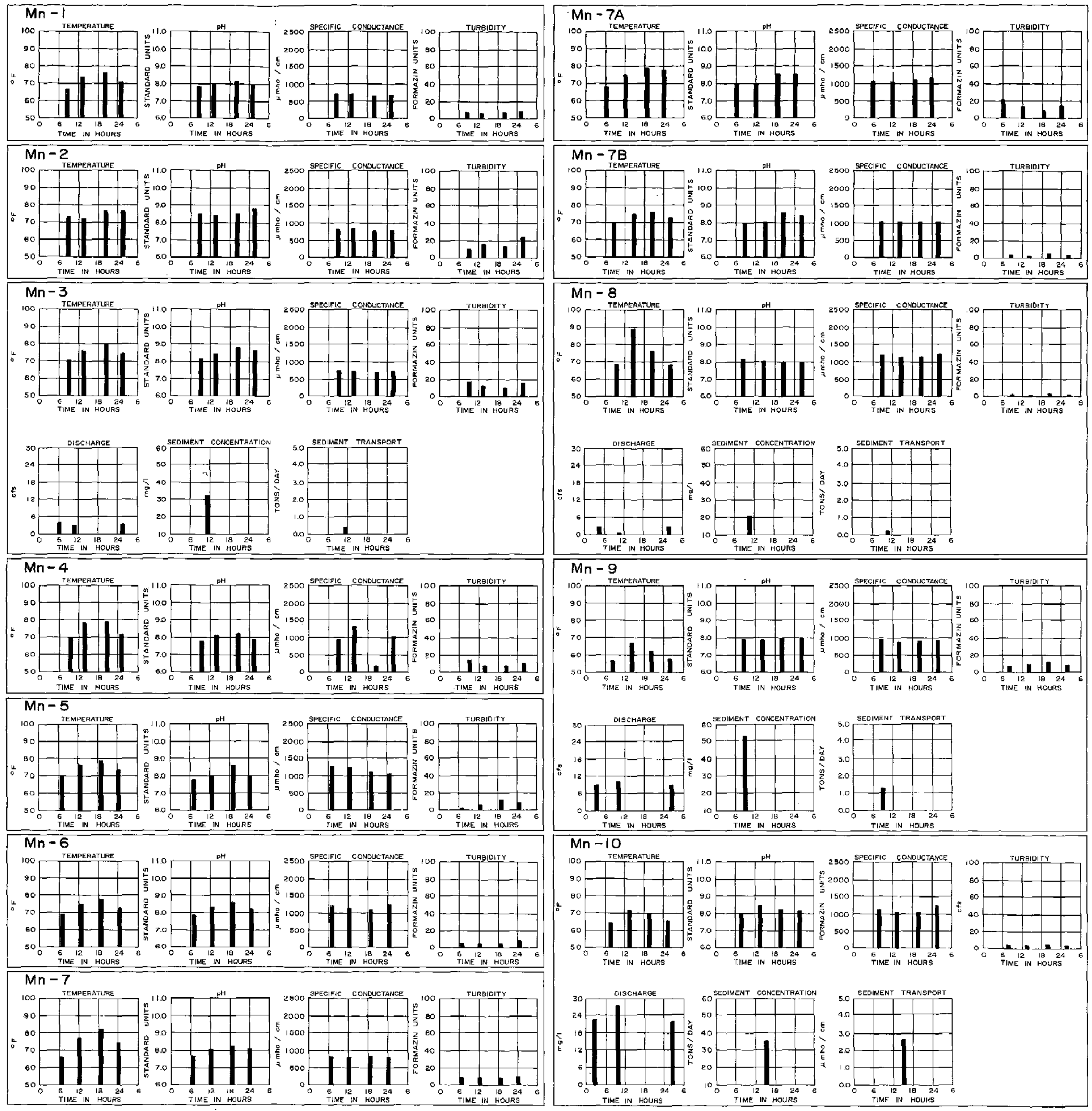
PHYSICAL WATER QUALITY INDICATORS IN THE MENOMONEE RIVER WATERSHED ON JULY 18, 1973



LEGEND

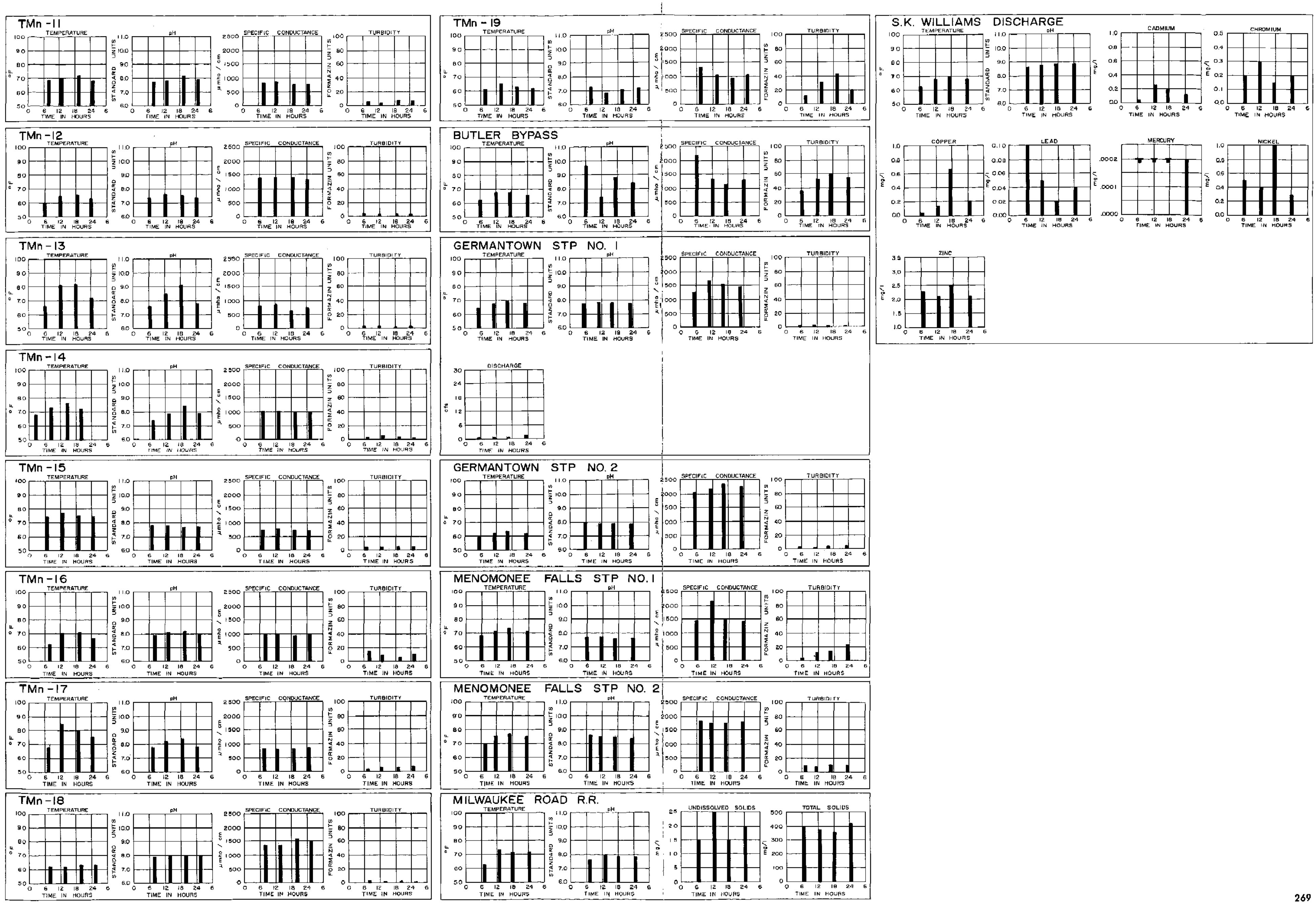
WATER QUALITY SAMPLING STATIONS

- ▼ INSTREAM STATION IDENTICAL TO THOSE USED IN SEWRPC AND SEWRPC-DNR WATER QUALITY MONITORING PROGRAMS (12)
- ▽ INSTREAM STATION TEMPORARILY ESTABLISHED FOR THE WATERSHED STUDY (5)
- ◆ MUNICIPAL SEWAGE TREATMENT PLANT EFFLUENT STATION INCLUDES ALL MUNICIPAL SEWAGE TREATMENT FACILITIES DISCHARGING WITHIN THE WATERSHED (3)
- ◇ INDUSTRIAL WASTEWATER DISCHARGE STATION INCLUDES POTENTIALLY SIGNIFICANT DISCHARGES (2)
- SAMPLING STATION REPRESENTATIVE OF DIFFERENT WATERSHED LAND USES (4)
- LAND AREA TRIBUTARY TO STATIONS TMn-16, TMn-17, TMn-18 AND TMn-19
- LESS THAN OR EQUAL TO INDICATED VALUE



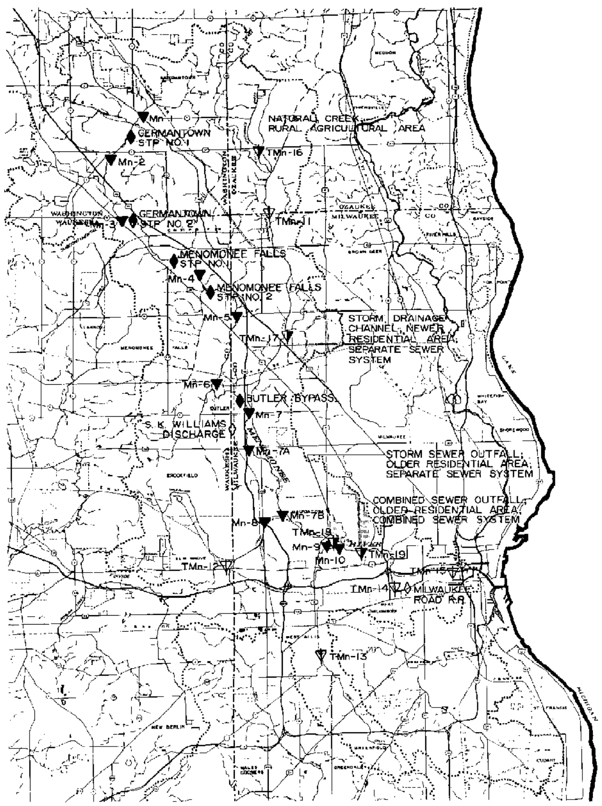
The above maps show the quality of surface waters in the Menomonee River watershed July 18, 1973, as determined by selected water quality indicators. Significant temporal variation in water temperatures occurred during the survey with most instream stations exhibiting a diurnal fluctuation of about 10°F with the highest temperatures generally occurring in the late afternoon-early evening thus reflecting the warming effect of the sun. Although diurnal temperature fluctuations occurred, the established temperature standards for the stream were satisfied as were the pH standards.

Source: Wisconsin Department of Natural Resources and SEWRPC.


TMn - 11
TMn - 12
TMn - 13
TMn - 14
TMn - 15
TMn - 16
TMn - 17
TMn - 18
TMn - 19
BUTLER BYPASS
GERMANTOWN STP NO. 1
DISCHARGE
GERMANTOWN STP NO. 2
MENOMONEE FALLS STP NO. 1
MENOMONEE FALLS STP NO. 2
MILWAUKEE ROAD R.R.
S.K. WILLIAMS DISCHARGE
TEMPERATURE
pH
SPECIFIC CONDUCTANCE
TURBIDITY
CADMIUM
CHROMIUM
COPPER
LEAD
MERCURY
NICKEL
ZINC
UNDISSOLVED SOLIDS
TOTAL SOLIDS
°F
STANDARD UNITS
µ mho / cm
FORMAZIN UNITS
mg/l
cfs
TIME IN HOURS

Map 66

PHYSICAL WATER QUALITY INDICATORS IN THE MENOMONEE RIVER WATERSHED ON AUGUST 6, 1974



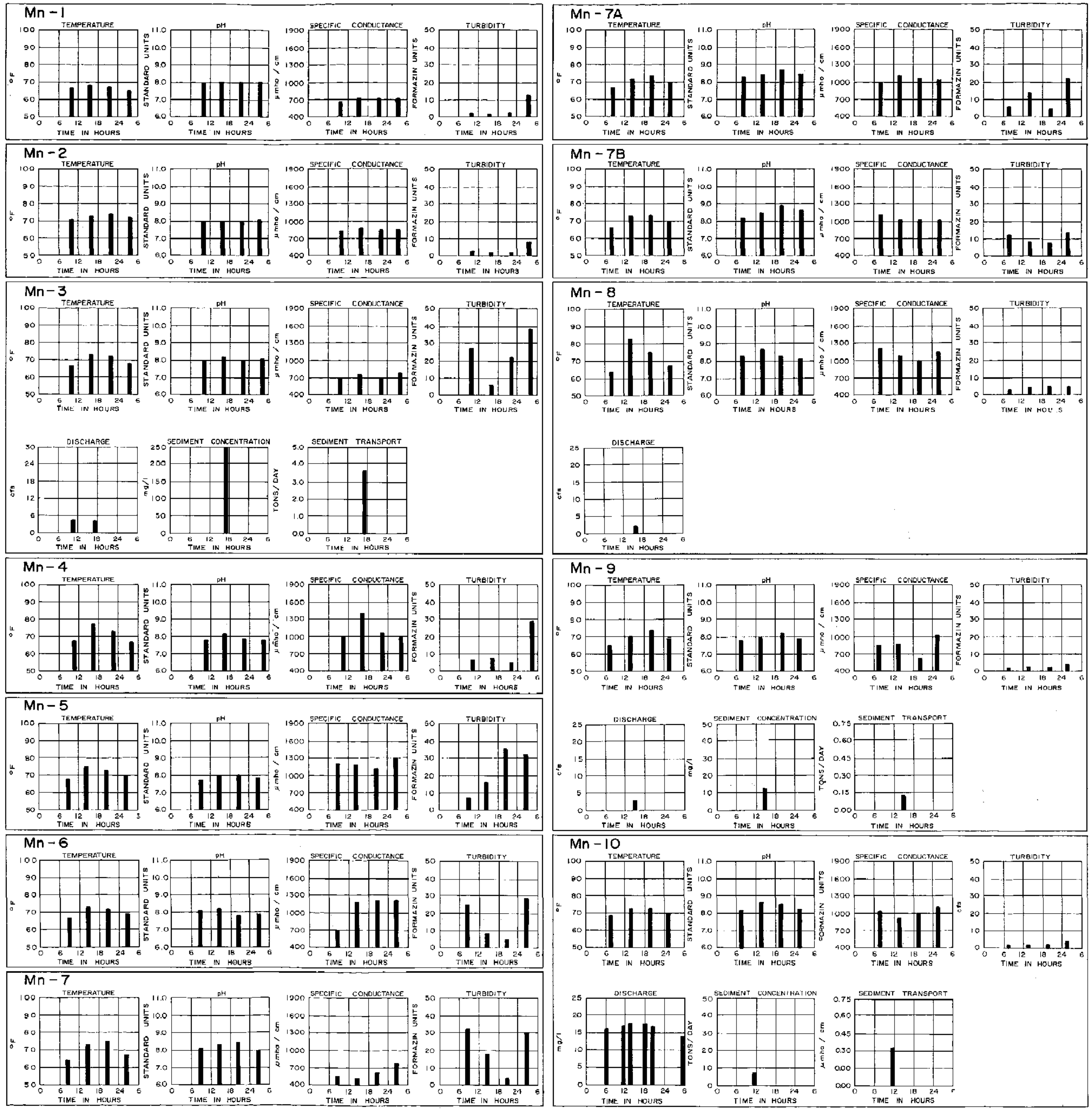
LEGEND

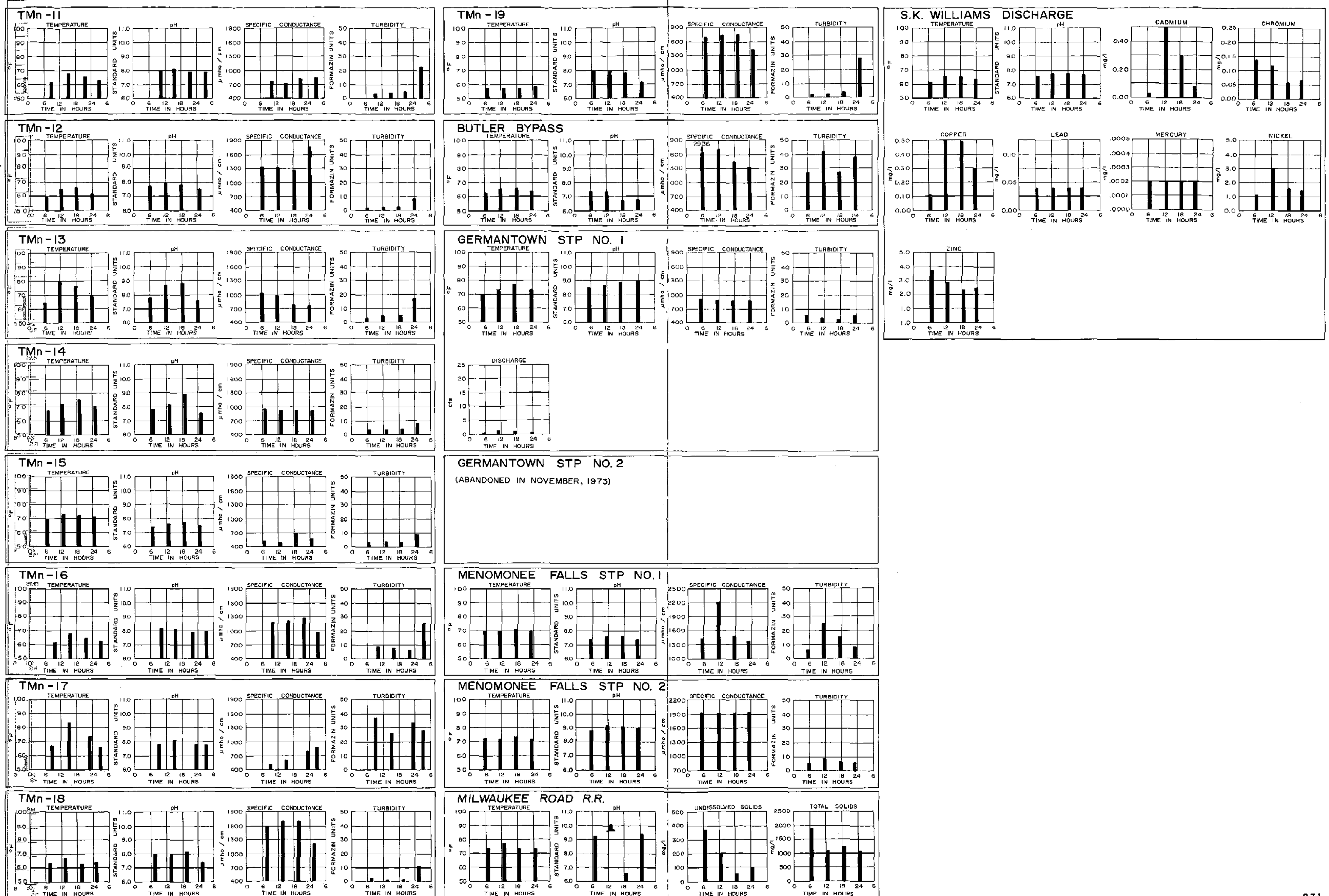
WATER QUALITY SAMPLING STATIONS

- ▼ INSTREAM STATION IDENTICAL TO THOSE USED IN SEWRPC AND SEWRPC-DNR WATER QUALITY MONITORING PROGRAMS (2)
- ▽ INSTREAM STATION TEMPORARILY ESTABLISHED FOR THE WATERSHED STUDY (5)
- ◆ MUNICIPAL SEWAGE TREATMENT PLANT EFFLUENT STATION INCLUDES ALL MUNICIPAL SEWAGE TREATMENT FACILITIES DISCHARGING WITHIN THE WATERSHED (5)
- ◇ INDUSTRIAL WASTEWATER DISCHARGE STATION INCLUDES POTENTIALLY SIGNIFICANT DISCHARGES (2)
- SAMPLING STATION REPRESENTATIVE OF DIFFERENT WATERSHED LAND USES (4)
- LAND AREA TRIBUTARY TO STATIONS TMn-16, TMn-17, TMn-18 AND TMn-19
- GREATER THAN OR EQUAL TO INDICATED VALUE

The above map shows the quality of surface waters in the Menomonee River watershed on August 6, 1974, as determined by selected water quality indicators. Diurnal temperature fluctuations of 5 to 10°F occurred along the Menomonee River and its major tributaries although the observed maximum daily temperatures did not exceed established temperature standards. In addition, the established standards for pH were satisfied throughout the watershed.

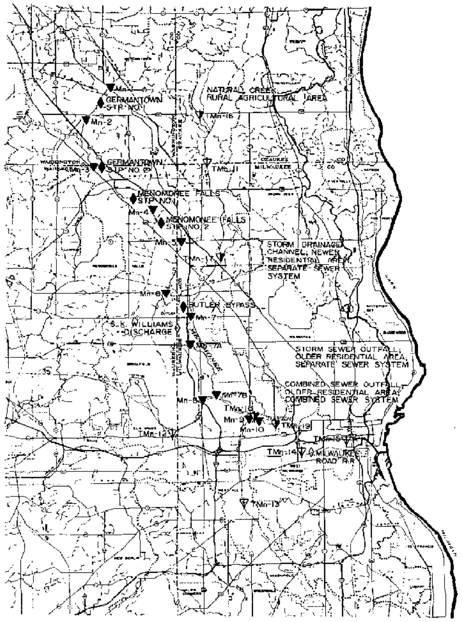
Source: Wisconsin Department of Natural Resources and SEWRPC.




TMn-11
TMn-12
TMn-13
TMn-14
TMn-15
TMn-16
TMn-17
TMn-18
TMn-19
BUTLER BYPASS
GERMANTOWN STP NO. 1
GERMANTOWN STP NO. 2
(ABANDONED IN NOVEMBER, 1973)
MENOMONEE FALLS STP NO. 1
MENOMONEE FALLS STP NO. 2
MILWAUKEE ROAD R.R.
S.K. WILLIAMS DISCHARGE
TEMPERATURE
pH
SPECIFIC CONDUCTANCE
TURBIDITY
DISCHARGE
UNDISSOLVED SOLIDS
TOTAL SOLIDS
CADMIUM
CHROMIUM
COPPER
LEAD
MERCURY
NICKEL
ZINC
TIME IN HOURS
STANDARD UNITS
FORMAZIN UNITS
μmho / cm
°F
mg/l
cfs

Map 67

CHEMICAL AND BIOLOGICAL WATER QUALITY IN THE MENOMONEE RIVER WATERSHED ON APRIL 4, 1973



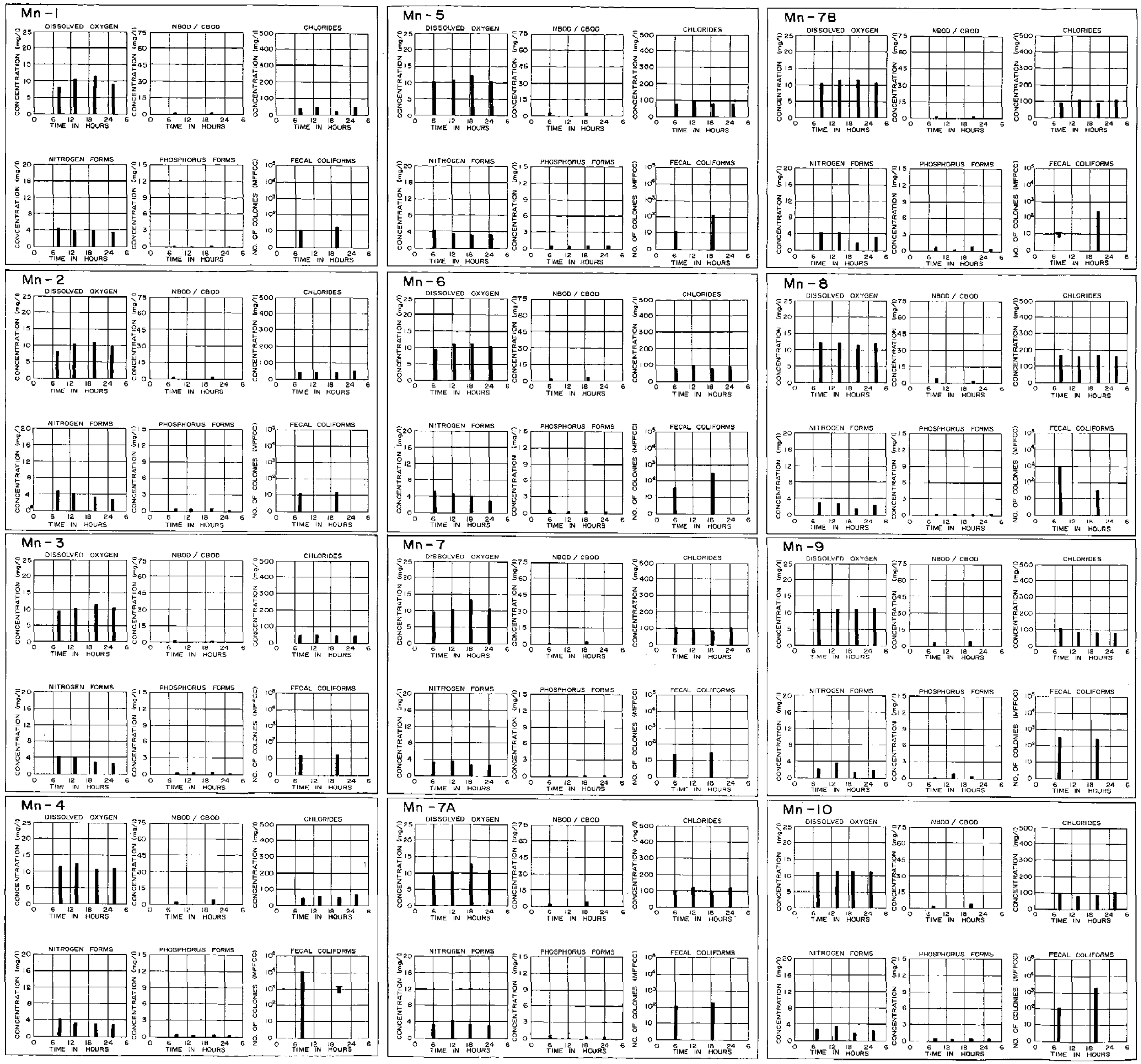
LEGEND

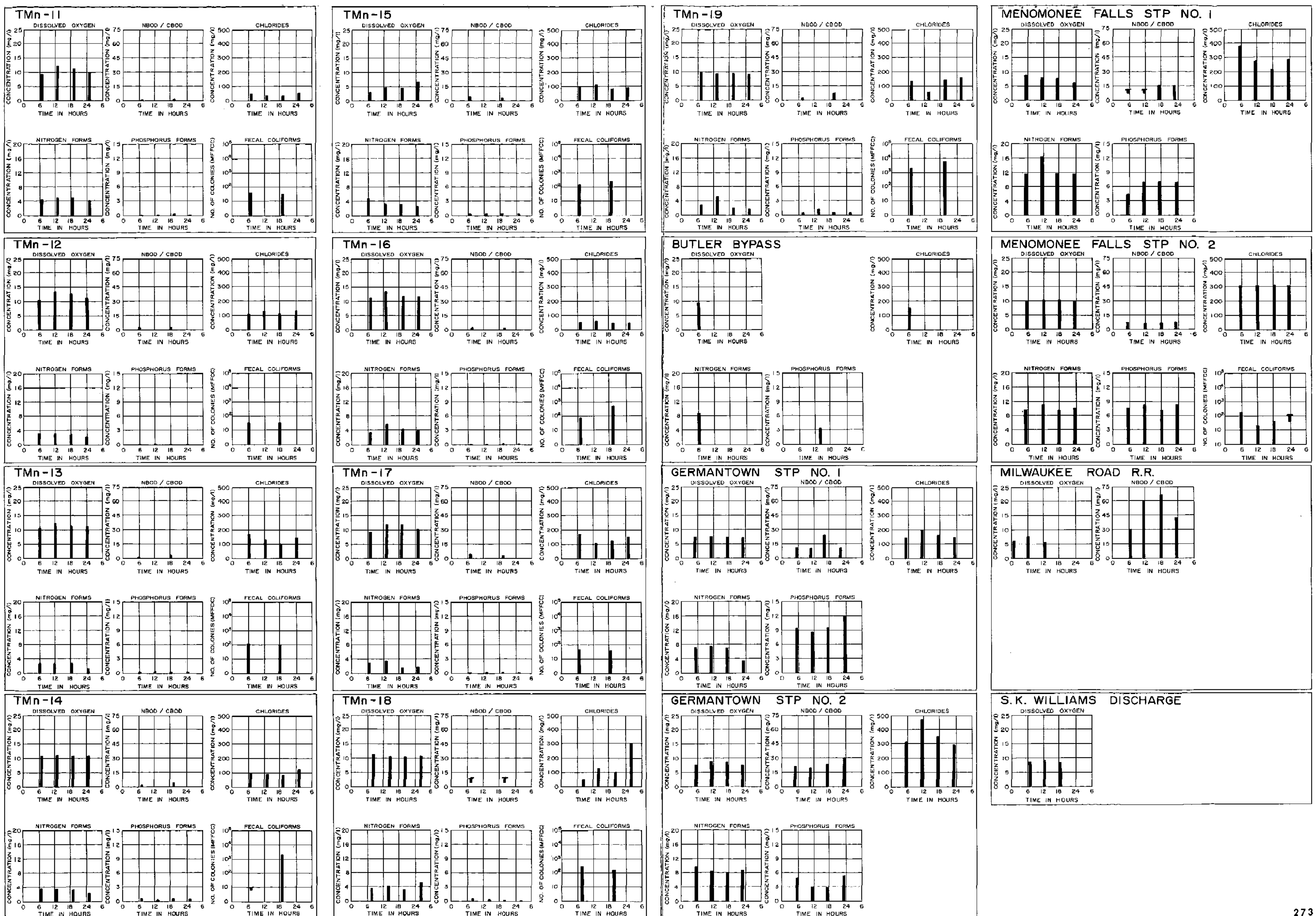
WATER QUALITY SAMPLING STATIONS

- INSTREAM STATION IDENTICAL TO THOSE USED IN SEWRPC AND SEWRPC-DNR WATER QUALITY MONITORING PROGRAMS (12)
- INSTREAM STATION TEMPORARILY ESTABLISHED FOR THE WATERSHED STUDY (5)
- MUNICIPAL SEWAGE TREATMENT PLANT EFFLUENT STATION INCLUDES ALL MUNICIPAL SEWAGE TREATMENT FACILITIES DISCHARGING WITHIN THE WATERSHED (5)
- INDUSTRIAL WASTEWATER DISCHARGE STATION INCLUDES POTENTIALLY SIGNIFICANT DISCHARGES (2)
- SAMPLING STATION REPRESENTATIVE OF DIFFERENT WATERSHED LAND USES (4)
- LAND AREA TRIBUTARY TO STATIONS TMn-16, TMn-17, TMn-18 AND TMn-19
- LESS THAN OR EQUAL TO INDICATED VALUE

The chemical and biological water quality of the stream system of the Menomonee River watershed as indicated by the synoptic water quality survey taken on April 4, 1973, reflected the wet weather conditions that existed during and before the survey. Pollutants washed off the land surface during wet weather have a significant impact on water quality conditions as do pollutants from separate and combined sewer overflows. High nutrient concentrations were found to exist along the entire length of the Menomonee River and along most of the Little Menomonee River and Little Menomonee Creek. Such concentration promotes excessive growths of algae and other aquatic plants which, in turn, may significantly detract from the appearance of the stream, cause odor problems, and contribute to fish kills. High fecal coliform bacteria counts also were found to exist along portions of the Menomonee River indicating the possible presence of disease-carrying organisms and the possible risk to the health of people who come in contact with the stream.

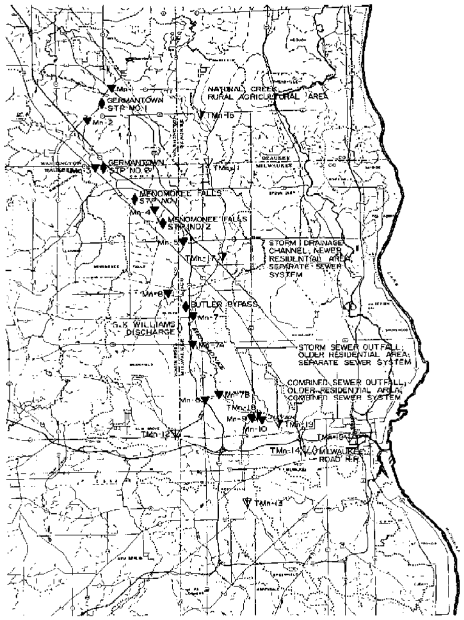
Source: Wisconsin Department of Natural Resources and SEWRPC.




TMn-11
TMn-12
TMn-13
TMn-14
TMn-15
TMn-16
TMn-17
TMn-18
TMn-19
BUTLER BYPASS
GERMANTOWN STP NO. 1
GERMANTOWN STP NO. 2
MENOMONEE FALLS STP NO. 1
MENOMONEE FALLS STP NO. 2
MILWAUKEE ROAD R.R.
S.K. WILLIAMS DISCHARGE
DISSOLVED OXYGEN
NBOD / CBOD
CHLORIDES
NITROGEN FORMS
PHOSPHORUS FORMS
FECAL COLIFORMS
CONCENTRATION (mg/l)
NO. OF COLONIES (MFFCC)
TIME IN HOURS

Map 68

CHEMICAL AND BIOLOGICAL WATER QUALITY INDICATORS IN THE MENOMONEE RIVER WATERSHED ON JULY 18, 1973



LEGEND

WATER QUALITY SAMPLING STATIONS

- ▼ INSTREAM STATION IDENTICAL TO THOSE USED IN SEWRPC AND SEWRPC-DNR WATER QUALITY MONITORING PROGRAMS (12)
- ▽ INSTREAM STATION TEMPORARILY ESTABLISHED FOR THE WATERSHED STUDY (5)
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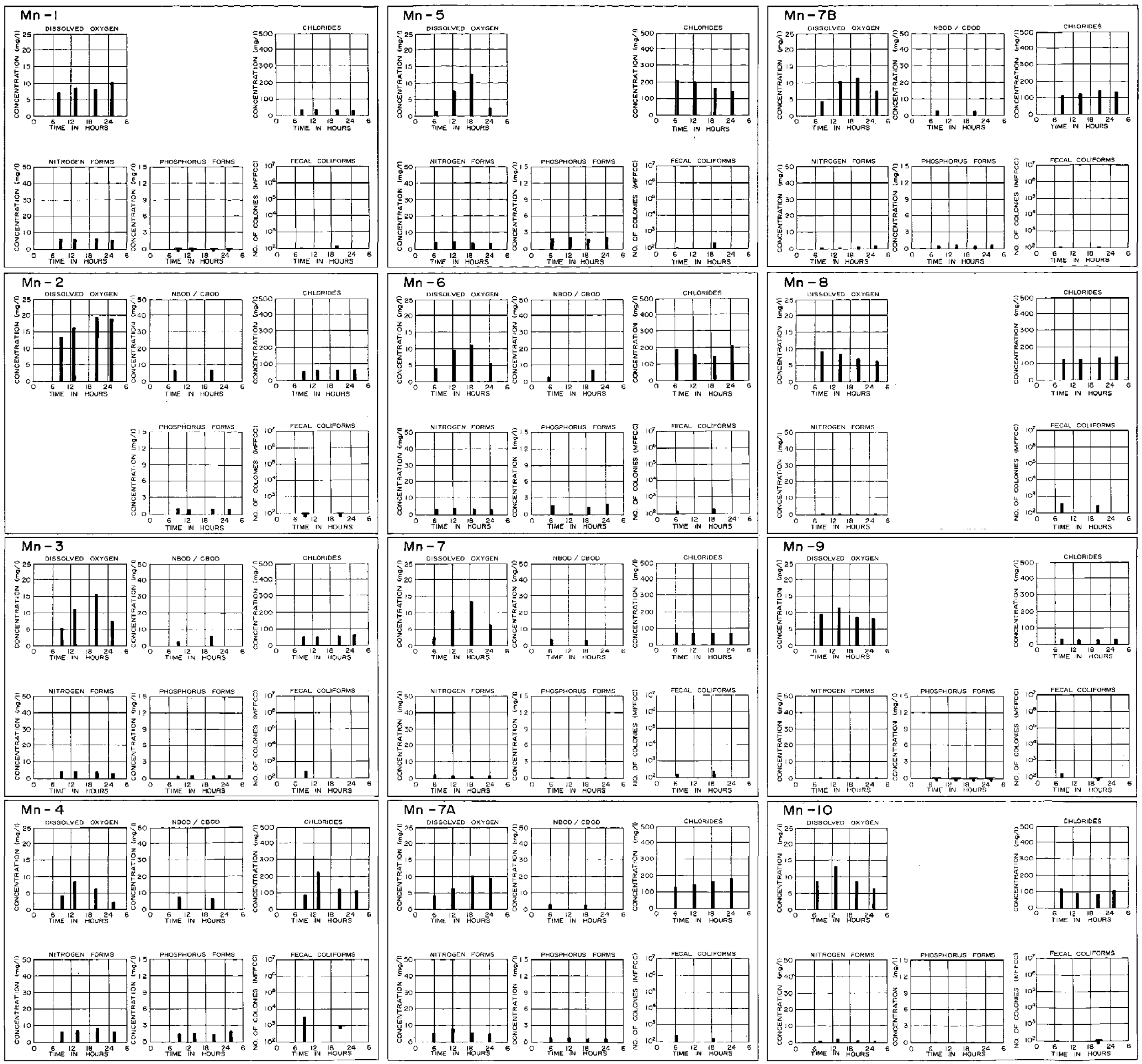
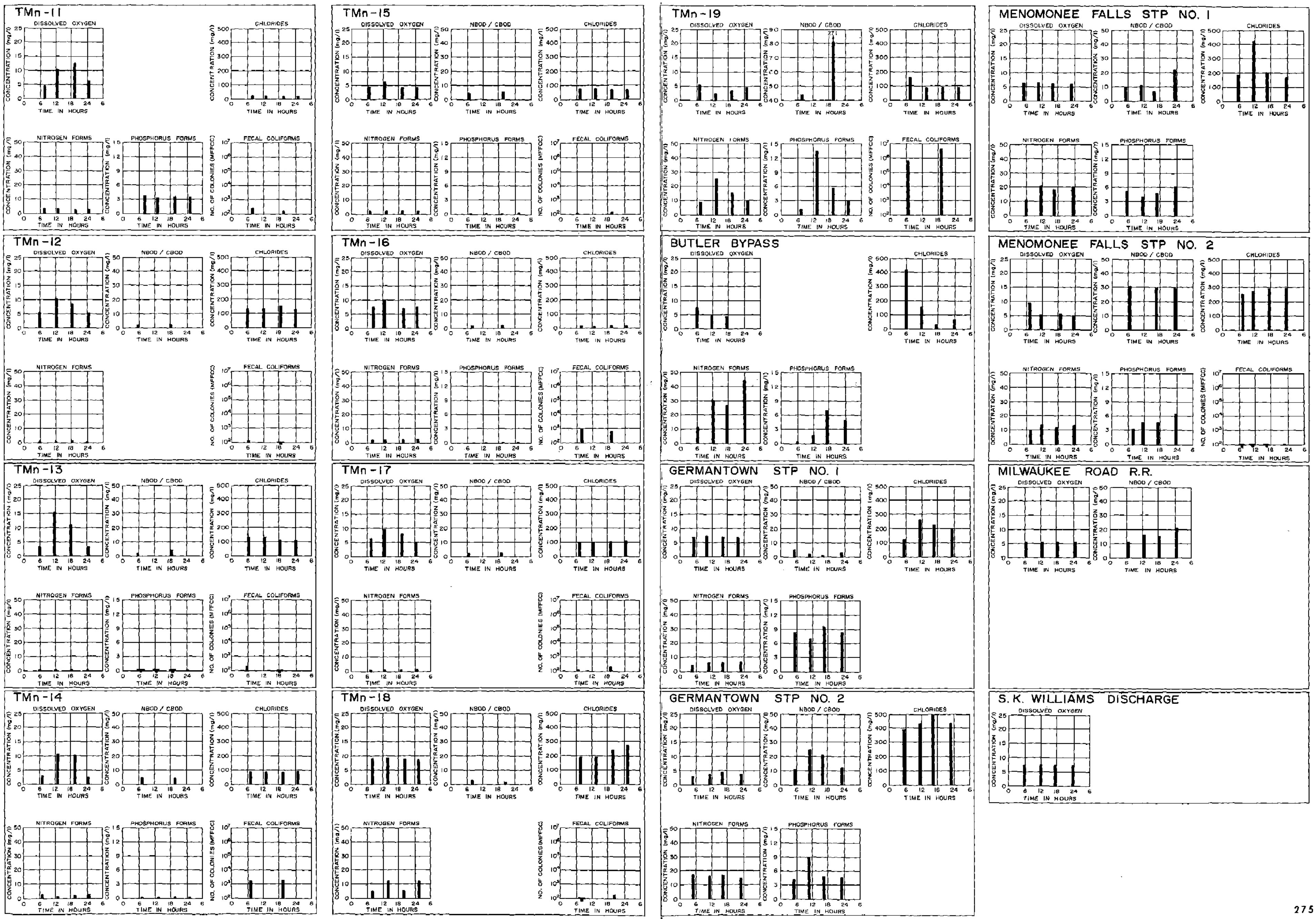
- SAMPLING STATION REPRESENTATIVE OF DIFFERENT WATERSHED LAND USES (4)
- LAND AREA TRIBUTARY TO STATIONS TMn-16, TMn-17, TMn-18 AND TMn-19
- LESS THAN OR EQUAL TO INDICATED VALUE

The dry conditions which occurred prior to the synoptic water quality survey which was conducted on July 18, 1973, affected both streamflow and water quality along the main stem of the Menomonee River. Because of the low streamflows, municipal sewage treatment plant discharges appeared to have particularly heavy impact on the conditions in the Menomonee River. With respect to those stream reaches intended for recreational use and for the preservation of fish and aquatic life, low levels of dissolved oxygen, high levels of fecal coliform bacteria, and high levels of total phosphorus were recorded. For example, substandard dissolved oxygen concentrations occurred along the entire length of the Menomonee River downstream of the Washington-Waukesha County line and along the entire length of the Little Menomonee River.

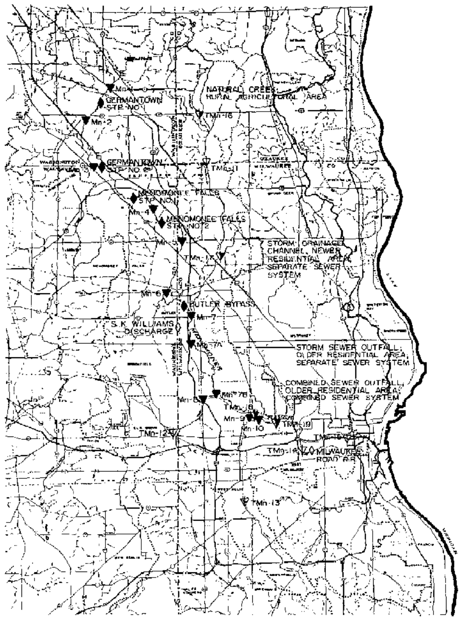
Source: Wisconsin Department of Natural Resources and SEWRPC.




TMn-11
TMn-12
TMn-13
TMn-14
TMn-15
TMn-16
TMn-17
TMn-18
TMn-19
BUTLER BYPASS
GERMANTOWN STP NO. 1
GERMANTOWN STP NO. 2
MENOMONEE FALLS STP NO. 1
MENOMONEE FALLS STP NO. 2
MILWAUKEE ROAD R.R.
S.K. WILLIAMS DISCHARGE
DISSOLVED OXYGEN
NBOD / CBOD
CHLORIDES
NITROGEN FORMS
PHOSPHORUS FORMS
FECAL COLIFORMS
CONCENTRATION (mg/l)
NO. OF COLONIES (MFFCC)
TIME IN HOURS

Map 69

CHEMICAL AND BIOLOGICAL WATER QUALITY INDICATORS IN THE MENOMONEE RIVER WATERSHED ON AUGUST 6, 1974



LEGEND

WATER QUALITY SAMPLING STATIONS

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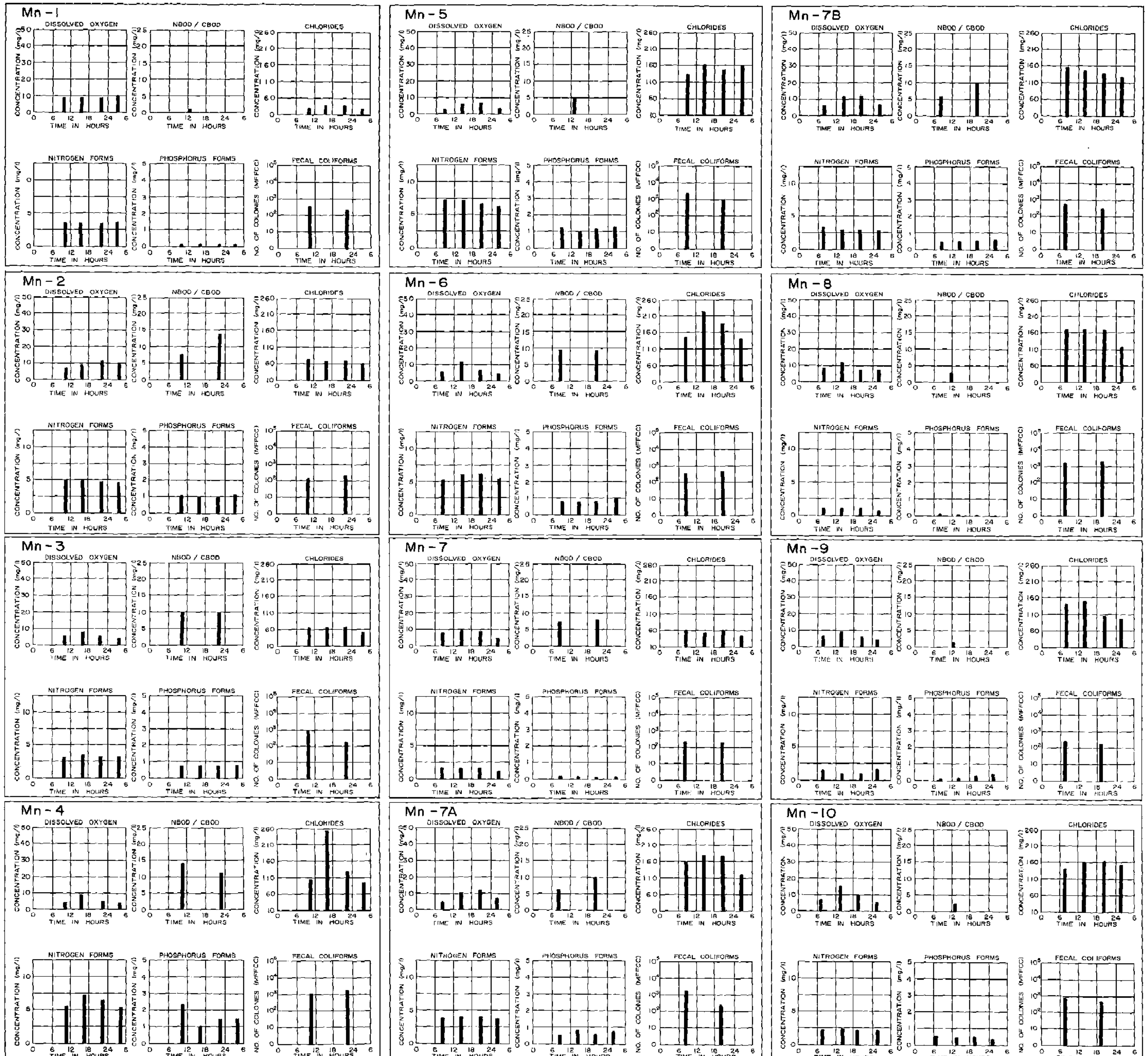
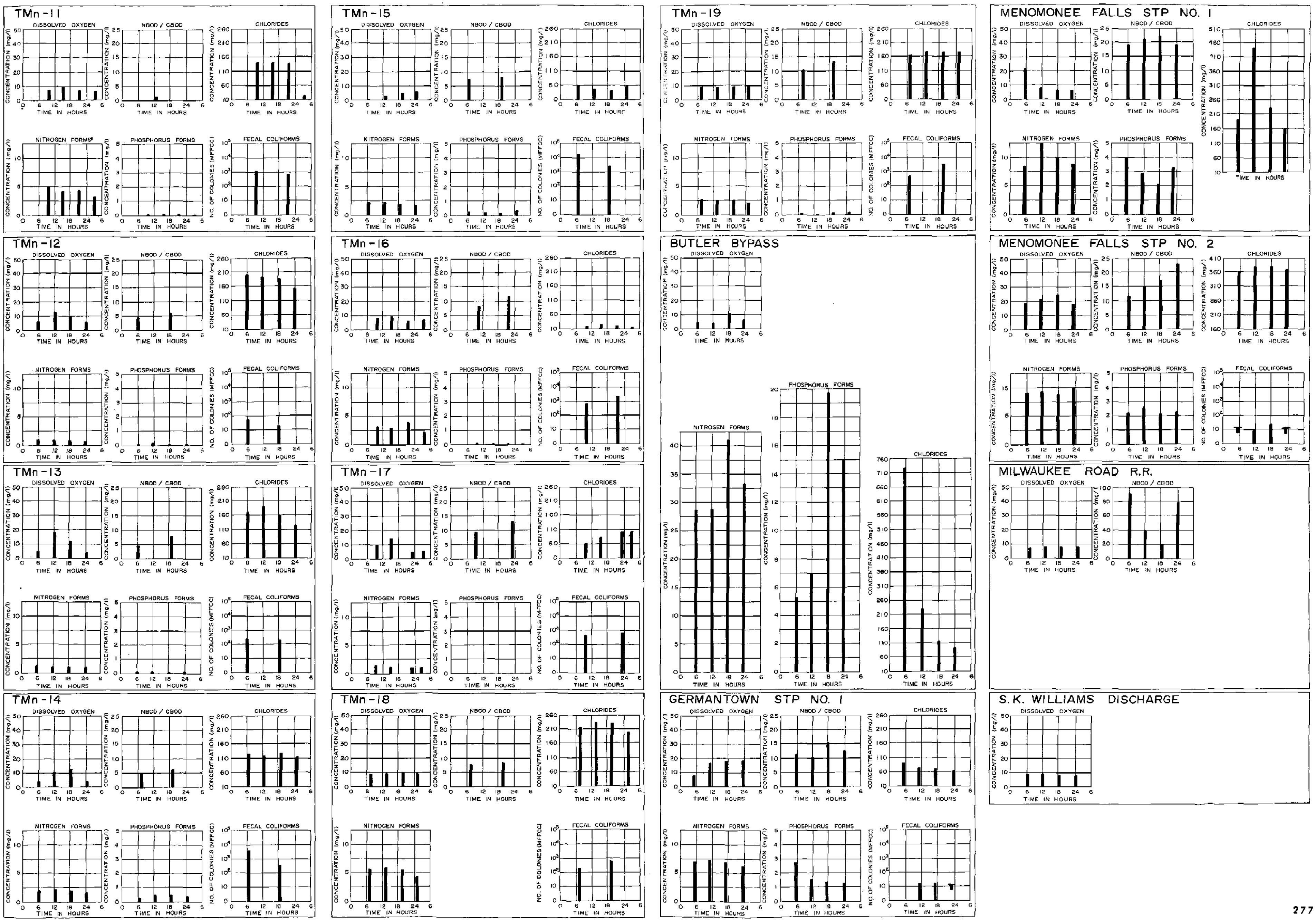
- SAMPLING STATION REPRESENTATIVE OF DIFFERENT WATERSHED LAND USES (4)
- LAND AREA TRIBUTARY TO STATIONS TMn-16, TMn-17, TMn-18 AND TMn-19
- LESS THAN OR EQUAL TO INDICATED VALUE

The lowest streamflows recorded during the three synoptic water quality surveys undertaken in the Menomonee River watershed occurred during survey 3 on August 6, 1974. Under such dry weather conditions, potential sources of pollutants are limited primarily to the municipal sewage treatment plants. With respect to the stream reaches intended for recreational use and for preservation of fish and aquatic life, high levels of fecal coliform bacteria and of total phosphorus were recorded along much of the Menomonee River, the Little Menomonee River, and Little Menomonee Creek.

Source: Wisconsin Department of Natural Resources and SEWRPC.





TMn-11
TMn-12
TMn-13
TMn-14
TMn-15
TMn-16
TMn-17
TMn-18
TMn-19
BUTLER BYPASS
GERMANTOWN STP NO. 1
MENOMONEE FALLS STP NO. 1
MENOMONEE FALLS STP NO. 2
MILWAUKEE ROAD R.R.
S.K. WILLIAMS DISCHARGE
DISSOLVED OXYGEN
NBOD / CBOD
CHLORIDES
NITROGEN FORMS
PHOSPHORUS FORMS
FECAL COLIFORMS
CONCENTRATION (mg/l)
NO. OF COLONIES (MFFCC)
TIME IN HOURS

Table 57

PRECIPITATION CONDITIONS DURING AND PRIOR TO THE SYNOPTIC WATER QUALITY SURVEYS

Synoptic Survey		Meteorologic Station	Daily Precipitation on (Day 1) and Before the Day of the Survey (Inches)									
Number	Date		1	2	3	4	5	6	7	8	9	10
1	April 4, 1973	Germantown	0.16	0.04	0.20	0.30	0.00	0.08	0.02	0.00	0.00	0.00
		Mt. Mary	0.18	0.05	0.11	0.38	0.28	0.04	0.04	0.00	0.00	0.00
		West Allis	0.36	0.11	0.03	0.18	0.77	0.00	0.09	0.01	0.00	0.00
		Average	0.23	0.07	0.11	0.29	0.35	0.04	0.05	0.00	0.00	0.00
		A.P.I.[a]	1.003	0.858	0.876	0.851	0.624	0.304	0.294	0.271	0.301	0.334
2	July 18, 1973	Germantown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
		Mt. Mary	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		West Allis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
		Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
		A.P.I.[a]	0.087	0.097	0.108	0.120	0.133	0.148	0.165	0.183	0.204	0.215
3	August 6, 1974	Germantown	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
		Mt. Mary	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00
		West Allis	0.00	0.00	0.02	0.00	0.69	0.00	0.00	0.00	0.01	0.00
		Average	0.00	0.00	0.01	0.10	0.23	0.00	0.00	0.00	0.00	0.00
		A.P.I.[a]	0.575	0.639	0.710	0.778	0.754	0.582	0.646	0.718	0.798	0.887

[a] *Antecedent precipitation index in inches. The A.P.I. at the end of a day is 0.9 times the A.P.I. at the end of the preceding day plus the precipitation, if any, on the day in question.*

Source: National Weather Service and SEWRPC.

The average flow of the Menomonee River at Wauwatosa during each survey was also compared to the 7 day-10 year low flow at that location in order to determine if the 7 day-10 year low flow was exceeded, in which case the water quality standards that support the adopted water use objectives would be applicable. Using the recorded streamflow of the Menomonee River at Wauwatosa as an index, it was determined that streamflows exceeded the 7 day-10 year low flow throughout the watershed during all three synoptic surveys.

Compared to the other two surveys, relatively wet conditions existed during and before Synoptic Survey 1. An average of 0.23 inches of rainfall occurred over the basin on the survey day, and rain occurred in the watershed on each of the six consecutive days prior to the survey—a total of 0.91 inches—with average daily amounts ranging from 0.04 to 0.35 inches. The API at the end of the day before Synoptic Survey 1 was 0.86. Streamflow conditions during Synoptic Survey 1 reflected the wet conditions that existed during and before the survey. Recorded flows rose steadily on the six days preceding the survey, and the average daily flow of 242 cfs on the Menomonee River at Wauwatosa on the survey day was about 65 times the 7 day-10 year low flow and would be exceeded on only about 7 percent of the days in a year. The most significant hydro-meteorologic feature of Synoptic Survey 1 is that washoff from the watershed land surface occurred on the day of the survey as well as on the six consecutive days preceding the survey. Thus one would expect instream water quality to reflect water quality constituents washed off the land surface, but the effect would not be so dramatic as the shock load of a single, short-term runoff event.

The driest moisture conditions occurred prior to Synoptic Survey 2 in that not only was precipitation absent in the watershed during the survey but the survey was preceded by seven consecutive days without any precipitation being recorded in the watershed. The API before the survey was about 0.10—by far the lowest of any of the surveys—and is indicative of very small precipitation amounts over a long period prior to the survey. As would be expected because of the prevailing precipitation conditions, streamflows during Synoptic Survey 2 were much lower than during Synoptic Survey 1—the average daily flow of the Menomonee River at Wauwatosa during the second survey was about one-tenth of that recorded during the first. The 24 cfs average daily streamflow recorded on the Menomonee River at Wauwatosa was about seven times the 7 day-10 year low flow for that location and could be expected to be exceeded on about half of the days in a year.

Municipal sewage treatment plant discharges would be expected to have a major input on Menomonee River water quality during Synoptic Survey 2 because these discharges comprised a significant fraction of the streamflow. The average daily streamflow recorded on the Menomonee River at the Washington-Waukesha County

Table 58

STREAMFLOW CONDITIONS DURING AND PRIOR TO THE SYNOPTIC WATER QUALITY SURVEYS

Synoptic Survey		Streamflow Station			Average Daily Discharge on (Day 1) and Before the Day of the Survey (cfs)							Percent of Days on Which Flow on (Day 1) Would be Reached or Exceeded	Ratio of Flow on Day 1 7 Day-10 Year Low Flow[a]
Number	Date	Stream	USGS Number	Location	1	2	3	4	5	6	7		
1	April 4, 1973	Menomonee River	04087120	At N. 70th Street in Wauwatosa	242	165	180	180	128	86	82	7.0	68.5
		Menomonee River	04087020	Washington-Waukesha County line	46	--	--	--	--	--	--	--	--
		Little Menomonee River	04087050	At Donges Bay Road in Mequon	10	--	--	--	--	--	--	--	--
		Underwood Creek	04087088	Near Menomonee River in Wauwatosa	28	--	--	--	--	--	--	--	--
		Honey Creek	04087119	Near Menomonee River in Wauwatosa	49	--	--	--	--	--	--	--	--
2	July 18, 1973	Menomonee River	04087120	At N. 70th Street in Wauwatosa	24	25	25	25	26	31	28	54.0	6.8
		Menomonee River	04087020	Washington-Waukesha County line	3.7	--	--	--	--	--	--	--	--
		Little Menomonee River	0408750	At Donges Bay Road in Mequon	0.5	--	--	--	--	--	--	--	--
		Underwood Creek	04087088	Near Menomonee River in Wauwatosa	3.1	--	--	--	--	--	--	--	--
		Honey Creek	04087119	Washington-Waukesha County line	9.7	--	--	--	--	--	--	--	--
3	August 6, 1974	Menomonee River	04087120	At N. 70th Street in Wauwatosa	16.5	17	14	21	22	19	19	75.0	4.7
		Menomonee River	04087020	Washington-Waukesha County line	3.8	--	--	--	--	--	--	--	--
		Little Menomonee River	04087050	At Donges Bay Road in Mequon	1.0	--	--	--	--	--	--	--	--
		Underwood Creek	04087088	Near Menomonee River in Wauwatosa	2.2	--	--	--	--	--	--	--	--
		Honey Creek	04087119	Near Menomonee River in Wauwatosa	3.2	--	--	--	--	--	--	--	--

[a] *The 7 day-10 year low flow at USGS Gage No. 04087120 is 3.5 cfs based on streamflow data for the period October 1, 1961, through September 30, 1973.*

Source: U. S. Geological Survey and SEWRPC.

line was 3.7 cfs. Effluent from the Village of Germantown Old Village sewage treatment plant would account for approximately 25 percent of this flow. Further downstream on the Menomonee River immediately above its confluence with the Little Menomonee River, the estimated average streamflow on the day of the survey was 10 cfs, and about 35 percent of this flow consisted of effluent from five municipal sewage treatment plants. Near the lower end of the watershed on the Menomonee River at Wauwatosa, approximately 15 percent of the average flow of 24 cfs on the day of the survey consisted of sewage treatment plant effluent.

With respect to antecedent precipitation conditions, Synoptic Survey 3 was intermediate between the first and second surveys. Precipitation did not occur in the watershed during the day of the survey or on the day before the survey. A total of 0.34 inches of precipitation occurred over the watershed on the second, third, and fourth days prior to the survey. The API at the start of Synoptic Survey 3 was 0.64 inches, which is three-fourths that of Synoptic Survey 1 and almost seven times that of Synoptic Survey 2. The lowest streamflows were observed during Synoptic Survey 3 even though the driest antecedent precipitation conditions occurred in association with the second synoptic survey. The average Menomonee River streamflow of 16.5 cfs at Wauwatosa during Synoptic Survey 3 was about two-thirds of that monitored at that location during Synoptic Survey 2. The 16.5 cfs discharge was approximately five times the 7 day-10 year low flow. Only about one-fourth of the days in a year would be expected to exhibit streamflows lower than what occurred during Synoptic Survey 3.

As in the preceding survey, effluent from municipal sewage treatment plants located along the Menomonee River would be expected to have a significant effect on Menomonee River water quality because of the prevailing low streamflow conditions that prevailed. Discharge from the Germantown Old Village sewage treatment plant accounted for an estimated 25 percent of the average daily streamflow of 3.8 cfs recorded on the Menomonee River at the Washington-Waukesha County line. Farther downstream on the mainstem, immediately above its confluence with the Little Menomonee River, effluent from four sewage treatment plants comprised about 60 percent of the estimated average streamflow of 7.5 cfs during Synoptic Survey 3. Sewage treatment plant effluent accounts for approximately 28 percent of the average Menomonee River discharge of 16.5 cfs recorded near the lower end of the basin at Wauwatosa.

The most significant hydro-meteorologic features of the second and third surveys is that dry conditions prevailed immediately prior to the surveys and, therefore, potential pollutants being carried by the low streamflows must be attributed to either point sources or to discharge of groundwater to the streams.

Temporal Water Quality Changes: Maps 64 through 69 clearly illustrate the diurnal water quality changes that occur not only within the stream system but also in the flow being discharged to the surface water system from municipal sewage treatment plants and from industrial sources and in runoff from the land. Instream diurnal changes are more pronounced under low flow conditions such as occurred during the second and third synoptic surveys than under high flow runoff conditions like those existing during the first synoptic survey. Instream biochemical processes, such as oxygen production by algae and aquatic plant photosynthesis during the day and oxygen use by algae and aquatic plant respiration during the night period, appear to markedly influence water quality conditions during low flow periods. Under more turbulent, high flow conditions, during which runoff is occurring from the land surface, instream diurnal fluctuations are subdued. The factors which cause those fluctuations are less effective because of the much larger volumes of water being carried in the stream channels.

Figure 59 illustrates low flow condition temporal water quality changes by showing the diurnal variation in temperature, chlorides, and dissolved oxygen that occurred during Synoptic Survey 3 at station Mn 10 on the Menomonee River at Wauwatosa. Streamflow was relatively uniform in that it varied from 14.0 to 17.6 cfs. The average discharge during the survey was 16.5 cfs which is only about four times the 7 day-10 year low flow.

Water temperature ranged from a low of 68°F during the early morning hours on August 6 to a high of 73.5°F during the early evening hours of that day. The recorded diurnal fluctuation is most probably the result of corresponding diurnal variations in air temperature and solar radiation.

Chloride concentrations ranged from a low of 139 mg/l during the early morning hours of August 6 to a high of 161 mg/l during the early evening hours of that day. The overall high concentrations—relative to headwater area low flow condition background levels of 20-50 mg/l—reflect treated sanitary sewage being discharged to the Menomonee River from the four municipal sewage treatment plants located upstream of station Mn 10. The noon to evening peak in chloride levels at the station is a direct result of the larger concentration and quantity of chloride being discharged from the four sewage treatment facilities during the morning and afternoon hours.

The concentration of dissolved oxygen varied from a low of 5.5 mg/l–63 percent saturation–during the early morning hours of August 7, 1974, to a high of 15.5 mg/l—185 percent supersaturation—shortly after noon on August 6, 1974. Mid-day supersaturated dissolved oxygen levels most probably resulted from photosynthetic production of oxygen by algae and other aquatic plants whereas low nighttime dissolved oxygen concentrations may be attributed to respiration by algae and aquatic plants.

A practical consequence of diurnal water quality fluctuations is that while the average level or concentration of key parameters might meet established water quality standards for recreational use and protection of fish and aquatic life, extremely high or low levels during the day may not meet the standards. For example, the average of four dissolved oxygen concentrations determined for station Mn 5 on the Menomonee River during Synoptic Survey 3 was 5.2 mg/l, which is above the minimum standard of 5.0 mg/l, for recreational use and preservation of fish and aquatic life. However, substandard oxygen levels of 3.3 and 3.8 mg/l were measured in the two samples taken at 9:00 a.m. on August 6 and 2:30 a.m. on August 7 during that survey.

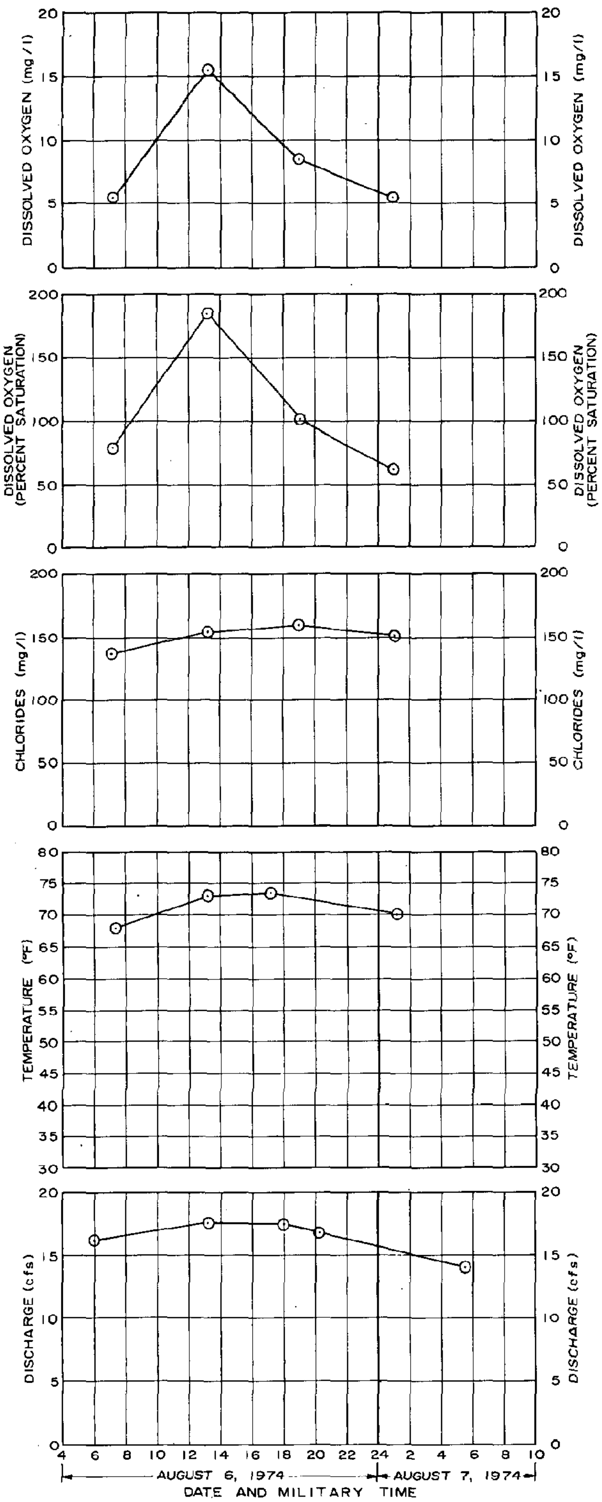
Figure 60 illustrates instream temporal variations during high streamflow-land surface runoff conditions by showing the diurnal variation in temperature, chlorides, and dissolved oxygen that occurred during Synoptic Survey 1 at Station Mn 10 on the Menomonee River at Wauwatosa. Streamflow was relatively high during this survey in that it averaged 242 cfs which is about 65 times the 7 day-10 year low flow and is about 15 times that which occurred during Synoptic Survey 3. Also, and as noted earlier in this chapter, precipitation occurred in the watershed during the survey as well as during the entire week preceding the survey and, therefore, washoff from the land surface was occurring during the survey.

As shown in Figure 60, very little fluctuation in water quality occurred during Synoptic Survey 1 compared with that which occurred during Synoptic Survey 3. Water temperature at station Mn 10 during Synoptic Survey 1 averaged 43°F, and minimum to maximum values differed by only 1 Fahrenheit degree. The average chloride concentration was 98 mg/l, minimum to maximum values differed by 29 mg/l. Dissolved oxygen averaged 11.1 mg/l—93 percent saturation—and fluctuated only 0.1 mg/l.

Spatial Water Quality Changes: The synoptic water quality surveys clearly indicate that water quality conditions change markedly from one location to another in the watershed stream system in response to a combination of

Figure 59

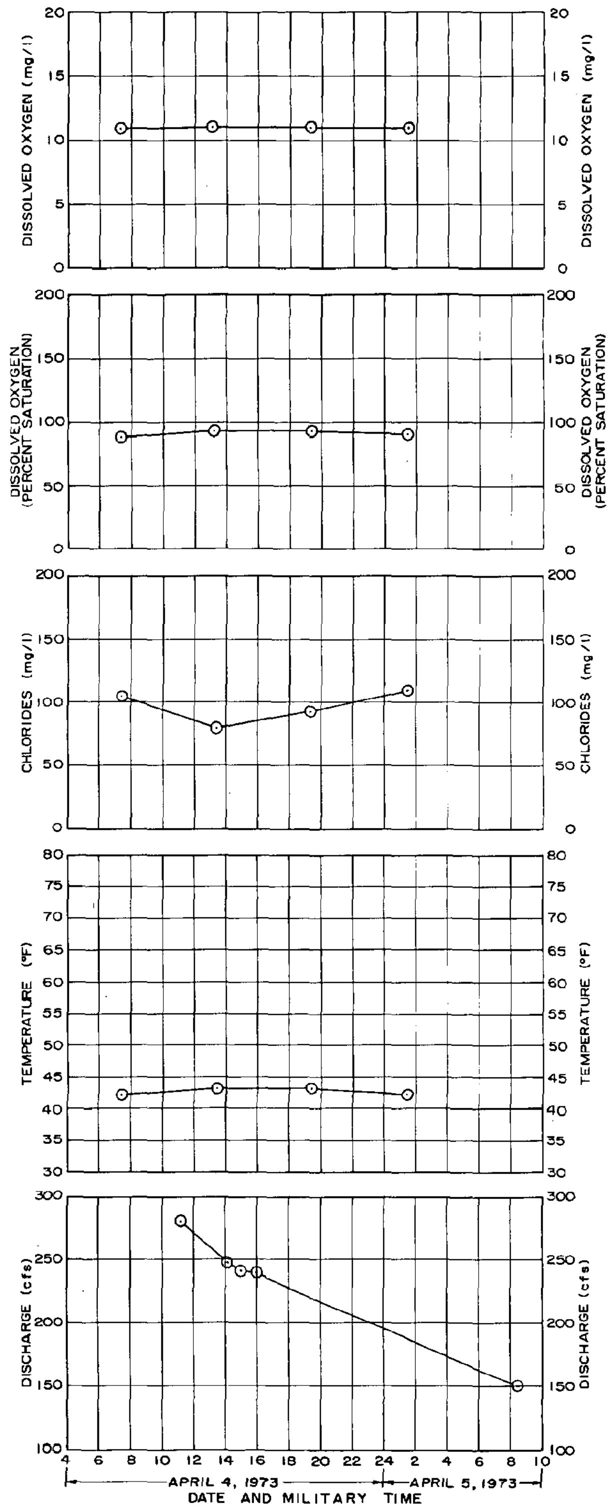
DIURNAL VARIATION IN SELECTED WATER QUALITY PARAMETERS AT AN INSTREAM STATION DURING A LOW FLOW PERIOD



Source: U. S. Geological Survey, Department of Natural Resources, and SEWRPC.

Figure 60

DIURNAL VARIATION IN SELECTED WATER QUALITY PARAMETERS AT AN INSTREAM STATION DURING A HIGH FLOW-LAND SURFACE RUNOFF PERIOD



Source: U. S. Geological Survey, Department of Natural Resources, and SEWRPC.

man's activities—primarily the discharge of treated and untreated sanitary sewage—and natural phenomena. Spatial variations in water quality are much more pronounced during low flow conditions than they are during high flow-land surface runoff periods. This appears to be primarily attributable to the impact of municipal sewage treatment plant discharges during low flow periods which contrasts with the dominant effect of land surface runoff during high flow periods.

Figure 61 shows typical low flow condition spatial water quality variations along the entire main stem of the Menomonee River as recorded during Synoptic Survey 3. The illustration is a profile of average values of discharge, temperature, chloride, specific conductance, dissolved oxygen, total phosphorus, and fecal coliform bacteria along the river and it includes the location of the sampling stations, influent streams, and the four municipal sewage treatment facilities that were in operation at the time of the survey. Inasmuch as average values of water quality parameters were used to develop Figure 61, the spatial variation in water quality parameters is somewhat understated.

Water quality conditions generally deteriorate in the downstream direction. This diminished quality is primarily attributable to discharge from municipal sewage treatment plants as illustrated by comparing water quality parameters at station Mn 1, which is upstream of the treatment facilities, to water quality parameters at station Mn 6, which is downstream of three of the four sewage treatment facilities. Average dissolved oxygen dropped from 9.2 to 7.0 mg/l between these two stations while five-day total biochemical oxygen demand increased from 1.6 to 9.2 mg/l. Chloride increased from 35 mg/l to 174 mg/l between the upstream and downstream stations and specific conductance—a measure of the total concentration of ionized substances—increased from 711 to 1,131 micro-mhos per centimeter. Fecal coliform bacteria levels increased from 385 to 570 MFFCC per 100 ml and the total phosphorus concentration increased from 0.05 to 0.81 mg/l.

Figure 62 illustrates spatial variations in water quality during high stream flow-land surface runoff conditions by showing a water quality profile of the Menomonee River for Synoptic Survey 1. Relative to the spatial changes that existed during the low flow conditions of Synoptic Survey 3, less spatial variation in water quality is evident during the high flow-land surface runoff conditions of Synoptic Survey 1. This may be illustrated by again comparing the level or concentration of selected parameters at stations Mn 1 and Mn 6. Average dissolved oxygen was almost the same at the two stations, 9.9 mg/l at the upstream location and 10.7 mg/l at the downstream location, while five-day total biochemical oxygen demand increased by a factor of 2.2 from 1.5 mg/l at station Mn 1 to 3.3 mg/l compared to the almost six-fold increase that occurred during Synoptic Survey 3. Chloride increased by a factor of 2.1 from 42 mg/l to 88 mg/l between the upstream and downstream stations compared to the approximately five-fold increase in concentration that occurred during the low flow conditions of Synoptic Survey 3. Specific conductance increased only about 20 percent from 713 to 890 micro-mhos per centimeter compared to the 60 percent increase that occurred during Synoptic Survey 3. Fecal coliform bacteria levels increased from 20 to 105 MFFCC per 100 ml from station Mn 1 to station Mn 6 with the absolute increase being less than that which occurred during Synoptic Survey 3. The total phosphorus concentration exhibited a five-fold increase, from 0.11 to 0.56 mg/l, compared to the increase by a factor of 16 that occurred during Synoptic Survey 3.

It is evident from the above data and analyses that the individual streams in the watershed exhibit markedly different water quality conditions throughout their length depending on the type and quantity of substances discharged to the stream. It is, therefore, common to find instances where water quality standards are met along some reaches of a stream while substandard conditions exist along other reaches. For example, the average dissolved oxygen concentration obtained for Station Mn 1 during Synoptic Survey 3 was 9.2 mg/l—the lowest of the four values at that station was 8.3 mg/l—which is well above the 5 mg/l minimum established for recreational use and preservation of fish and aquatic life. In contrast, the average concentration at Station Mn 15 near the outlet of the watershed was a substandard 3.1 mg/l—with the lowest of the four values at that station being 0.4 mg/l.

Assessment of Water Quality Relative to Water Quality Standards: The comprehensive water quality data obtained from the three synoptic surveys were used to assess the quality of the watershed's surface water system—as it existed on those days—relative to the water quality standards that support the restricted use and the recreational and fish and aquatic life use objectives that have been established for various portions of the watershed stream system. Such a comparative analysis must be done in the context of the concurrent hydrologic conditions since the water quality standards are not intended to be satisfied under all streamflow conditions. As discussed earlier in this chapter, however, data for the daily stream gage on the Menomonee River indicate that watershed-wide streamflows during all three surveys were in excess of the 7 day-10 year low flow above which the water quality standards are to be met.

The comparative analysis of observed water quality and the standards was based on six parameters: temperature, dissolved oxygen, pH, fecal coliform bacteria, total phosphorus, and ammonia. Critical limits on the first four parameters are explicitly set forth in the adopted standards whereas critical values of the last two parameters are implicit in the standards in that they are taken from Water Quality Criteria[37] which is explicitly referenced in the adopted water quality standards.

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[37] *Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, April 1968, Federal Water Pollution Control Administration, 1972.*

In carrying out the comparative analysis for a given synoptic survey, the water quality at a sampling site was considered substandard for a given parameter if any of the water quality analyses for that parameter, as obtained over the approximately 24-hour sampling period, were above or below the specified limits. That is, water quality was assessed on the basis of individual determinations made for each parameter as opposed to using values averaged over the day of the survey.

A precise comparison of observed fecal coliform bacteria concentrations to the specified standards could not be made because of the manner in which the standards are stated. For example, the fecal coliform bacteria standard for the restricted water use objective states that the fecal coliform count shall not exceed a monthly geometric mean of 1,000 colonies per 100 ml based on not less than five samples per month nor shall the count exceed a monthly geometric mean of 2,000 colonies per 200 ml in more than 10 percent of all samples during a month. Inasmuch as each 24-hour synoptic survey did not include the requisite large number of samples taken over a one-month period, the restricted use objective fecal coliform bacteria standard was assumed to be violated during a particular survey at a location if any of the fecal coliform counts obtained at that location exceeded 2,000 colonies per 100 ml. Similarily, the recreational use and fish and aquatic life standard was assumed to be exceeded during a particular survey at a sampling station if any of the fecal coliform counts exceeded 400 colonies per 100 ml.

Synoptic Survey 1: The results of a comparative analysis of the water quality existing during Synoptic Survey 1 and the water quality set forth in the adopted standards are summarized on Map 70. A set of parallel curvilinear lines is used on Map 70 to indicate which of the standards are exceeded and along what stream reaches.

With respect to those stream reaches intended for recreational use and fish and aquatic life use, the water quality during the survey satisfied the temperature, dissolved oxygen, pH, and ammonia standards throughout the watershed. The fecal coliform bacteria standard of 400 colonies per 100 ml was exceeded at only two locations in the watershed, both of them on the main stem of the Menomonee River. One location was in the vicinity of the Village of Menomonee Falls and is probably attributable to the discharge of untreated sanitary sewage from the Village of Menomonee Falls system through one of the flow relief points shown on Map 61. The other location is in the vicinity of N. 70th Street in the City of Wauwatosa and, although land surface runoff was occurring during this synoptic survey, this latter reach of substandard fecal coliform bacteria levels is upstream of the combined sewer service area and therefore the high coliform counts may not be attributable to combined sewer overflows. There is, however, as shown on Map 61, a cluster of sanitary sewerage system flow relief devices in the City of Wauwatosa that may be responsible for what appears to be a localized discharge of fecal coliform bacteria into the Menomonee River.

Levels of the sixth parameter, total phosphorus, exceeded the recreational use and fish and aquatic life use standard of 0.10 mg/l throughout the entire length of the Menomonee River designated for those uses as well as along most of the Little Menomonee River and Little Menomonee Creek which are also designated for those uses. Total phosphorus levels in excess of 0.10 mg/l on the Menomonee River may be traced in part to discharge of this nutrient from the five municipal sewage treatment plants that existed on the river during Synoptic Survey 1. As indicated in Table 42, samples of effluent from the Germantown Old Village and County Line plants, from the Menomonee Falls Pilgrim Road and Lilly Road plants, and the Butler facility revealed average total phosphorus concentrations of 9.3, 4.1, 6.4, 7.6, and 3.1 mg/l during Synoptic Survey 1. The fact that the phosphorus standards also were exceeded on stream reaches not influenced by municipal sewage treatment plant discharges is another indication that excessive phosphorus loadings are imposed on the stream from rural and urban diffuse sources.

Dissolved oxygen, pH, and fecal coliform standards are applicable to those stream reaches intended for restricted use. Surface water quality in these reaches met the dissolved oxygen and pH standards during Synoptic Survey 1 but substandard fecal coliform bacteria counts—in excess of 2,000 colonies per 100 ml—were observed on the main stem of the Menomonee River in the City of Milwaukee downstream of the Hawley Road crossing. These high fecal coliform levels are probably partly the result of combined sewer discharge inasmuch as this river reach contains combined sewer outfalls that were discharging during Synoptic Survey 1 because of the precipitation that was occurring. For example, two samples taken during Synoptic Survey 1 at the Hawley Road combined sewer outfall contained 3,100 and 8,500 colonies of fecal coliform bacteria per 100 ml. It is interesting to note, however, that the river reach downstream of Hawley Road also exhibited excessive fecal coliform counts during the other two surveys even though dry weather conditions existed during and prior to those surveys.

Additional insight into the nature of the watershed water quality phenomena under high flow-land surface runoff conditions results from analyzing the mass flow of selected constituents during Synoptic Survey 1. Consider the conservative substance chloride, for example. The rate of discharge of chloride from the five municipal sewage treatment facilities to the Menomonee River during the survey is estimated at about 9,000 pounds per day compared to the rate at which chloride was being transported from the watershed by the Menomonee River at N. 70th Street in Wauwatosa, which is estimated at 130,000 pounds per day. Therefore, chloride was being discharged from the watershed during Synoptic Survey 1 at a rate that was about 14 times that at which it was being supplied by the sewage treatment plants thereby indicating the importance of diffuse sources under high flow-land surface runoff conditions like those that existed during Synoptic Survey 1. Total phosphorus

Figure 61

SPATIAL VARIATIONS IN SELECTED WATER QUALITY PARAMETERS ALONG THE MENOMONEE RIVER WATERSHED DURING A LOW FLOW PERIOD

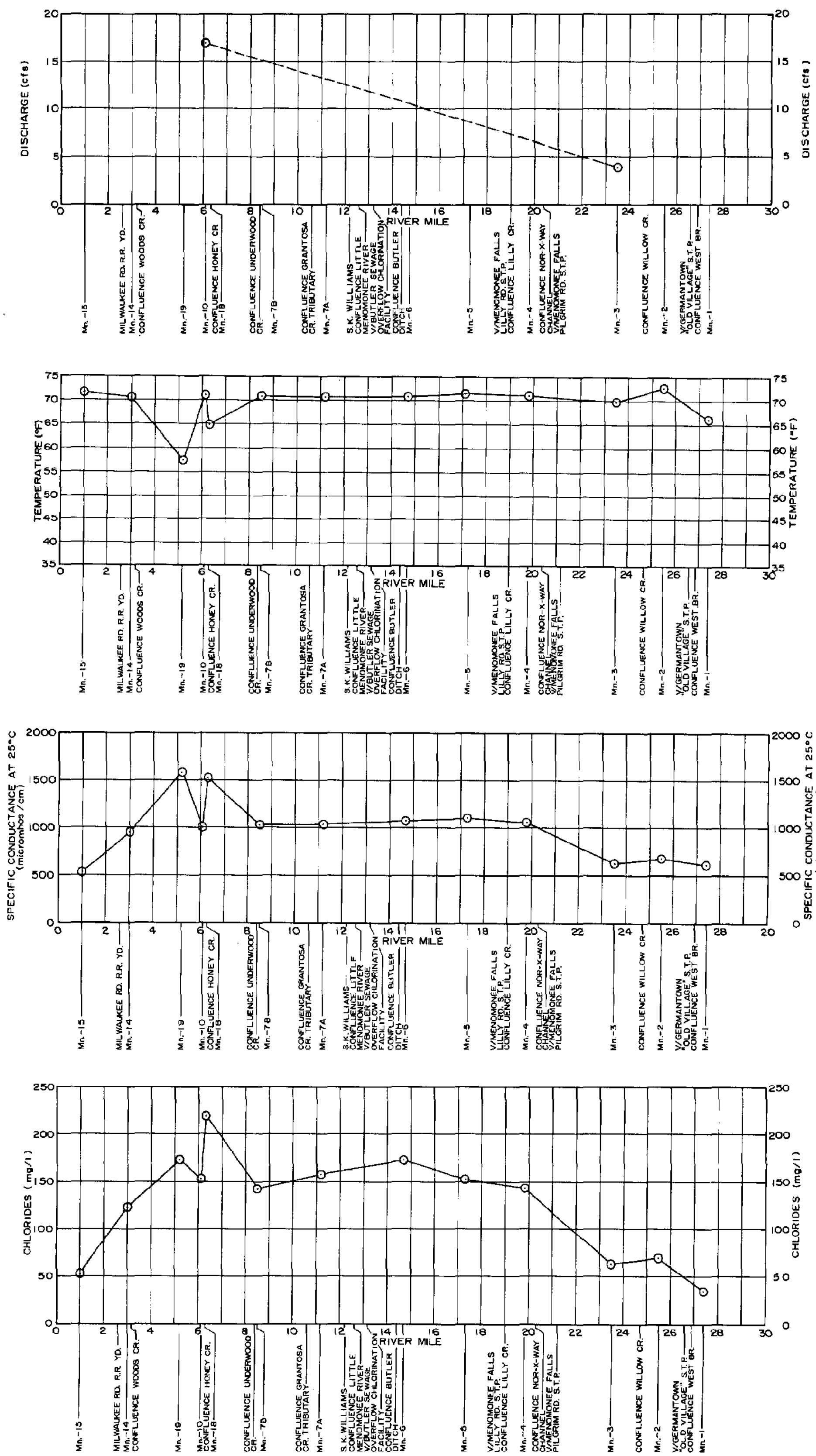


Figure 62

SPATIAL VARIATIONS IN SELECTED WATER QUALITY PARAMETERS ALONG THE MENOMONEE RIVER DURING A HIGH FLOW-LAND SURFACE RUNOFF PERIOD

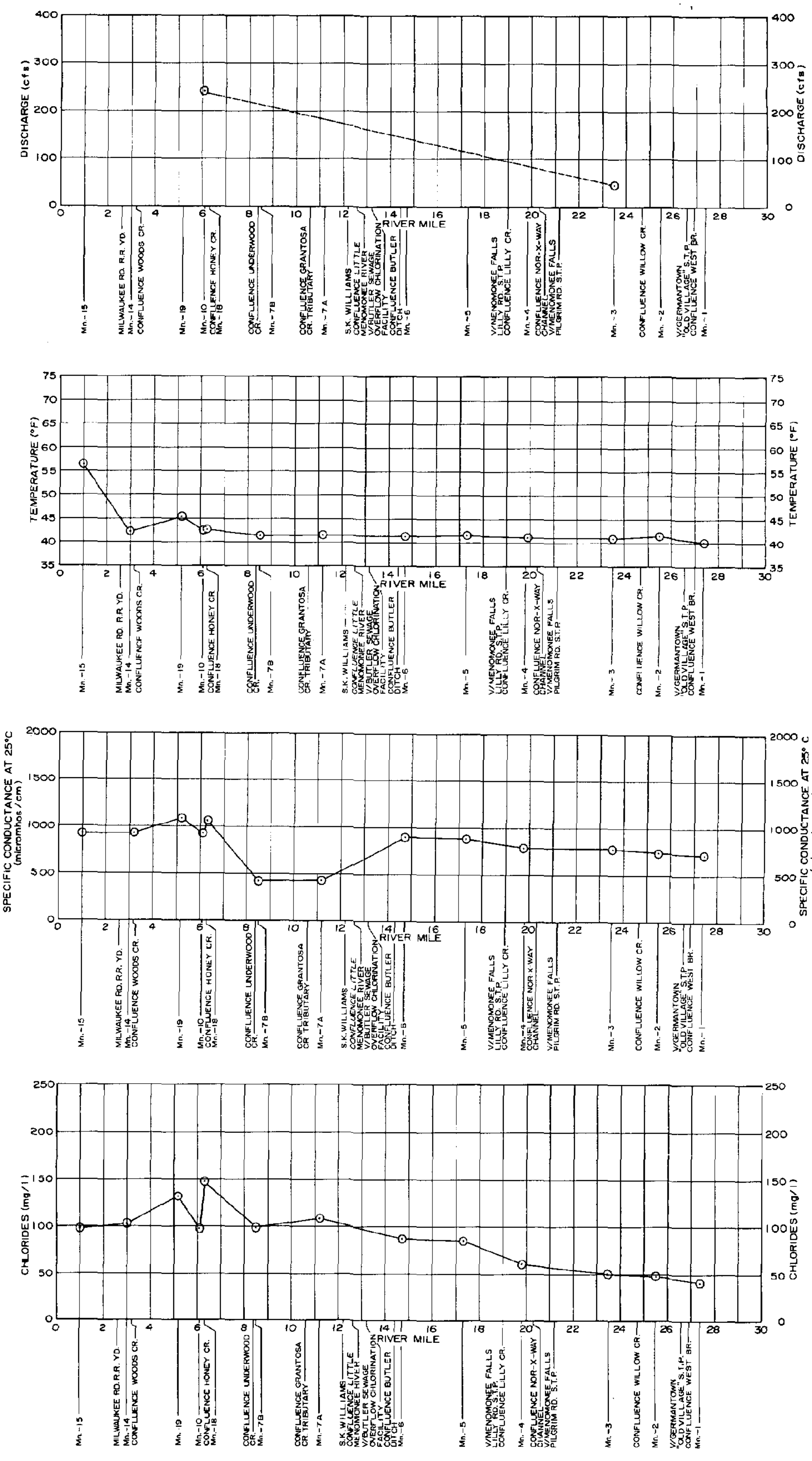
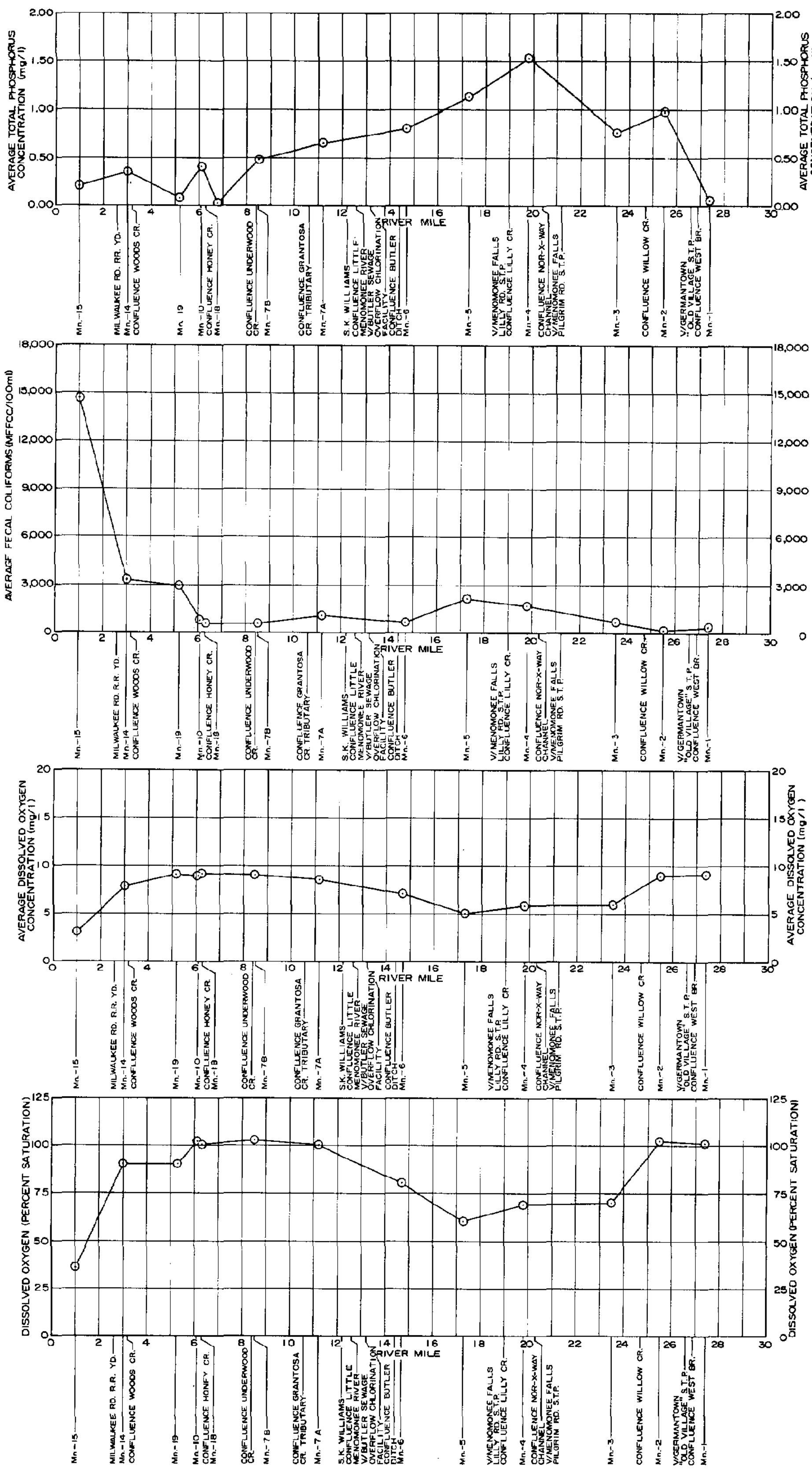
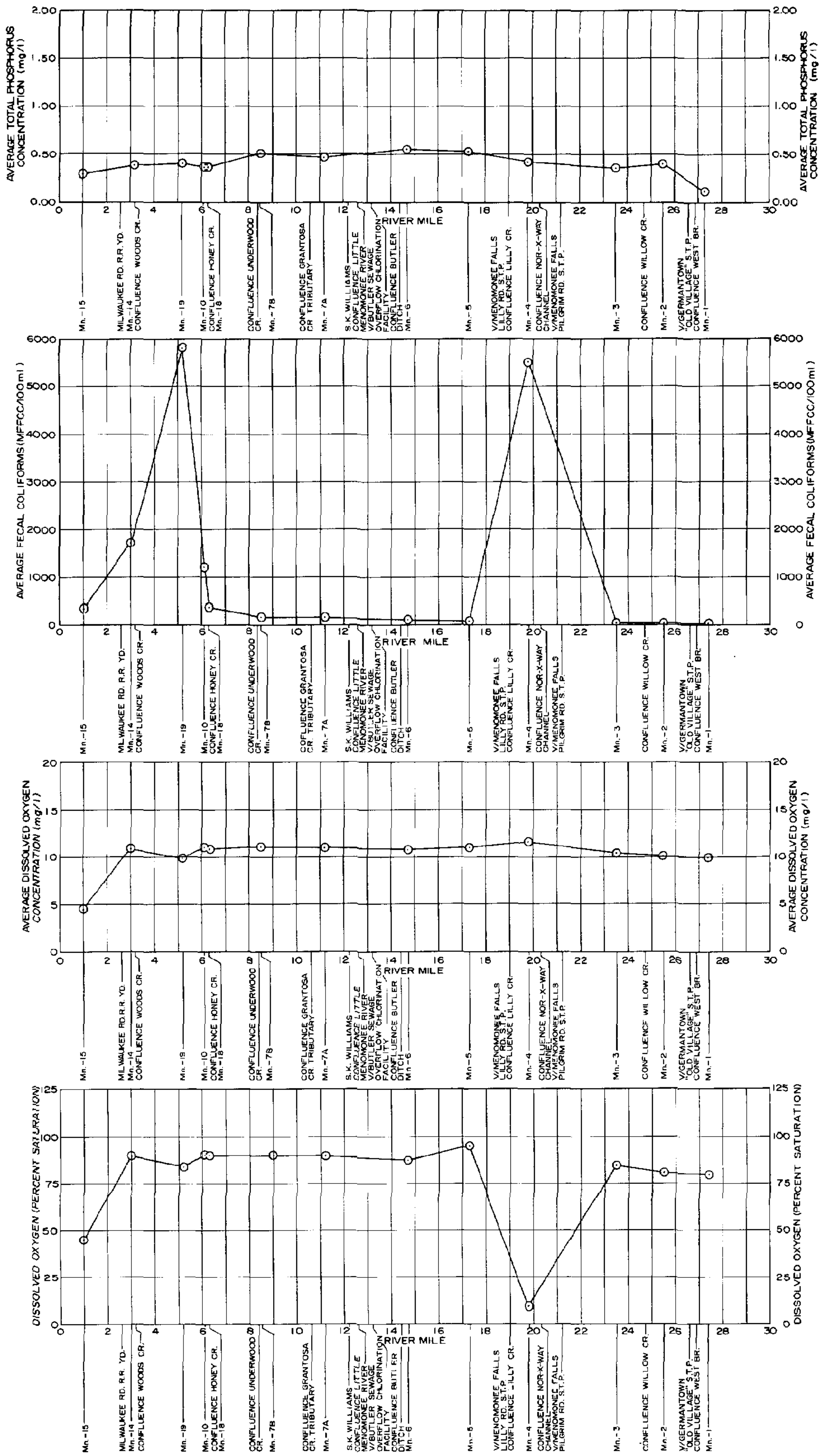


Figure 61 (continued)



Source: U. S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

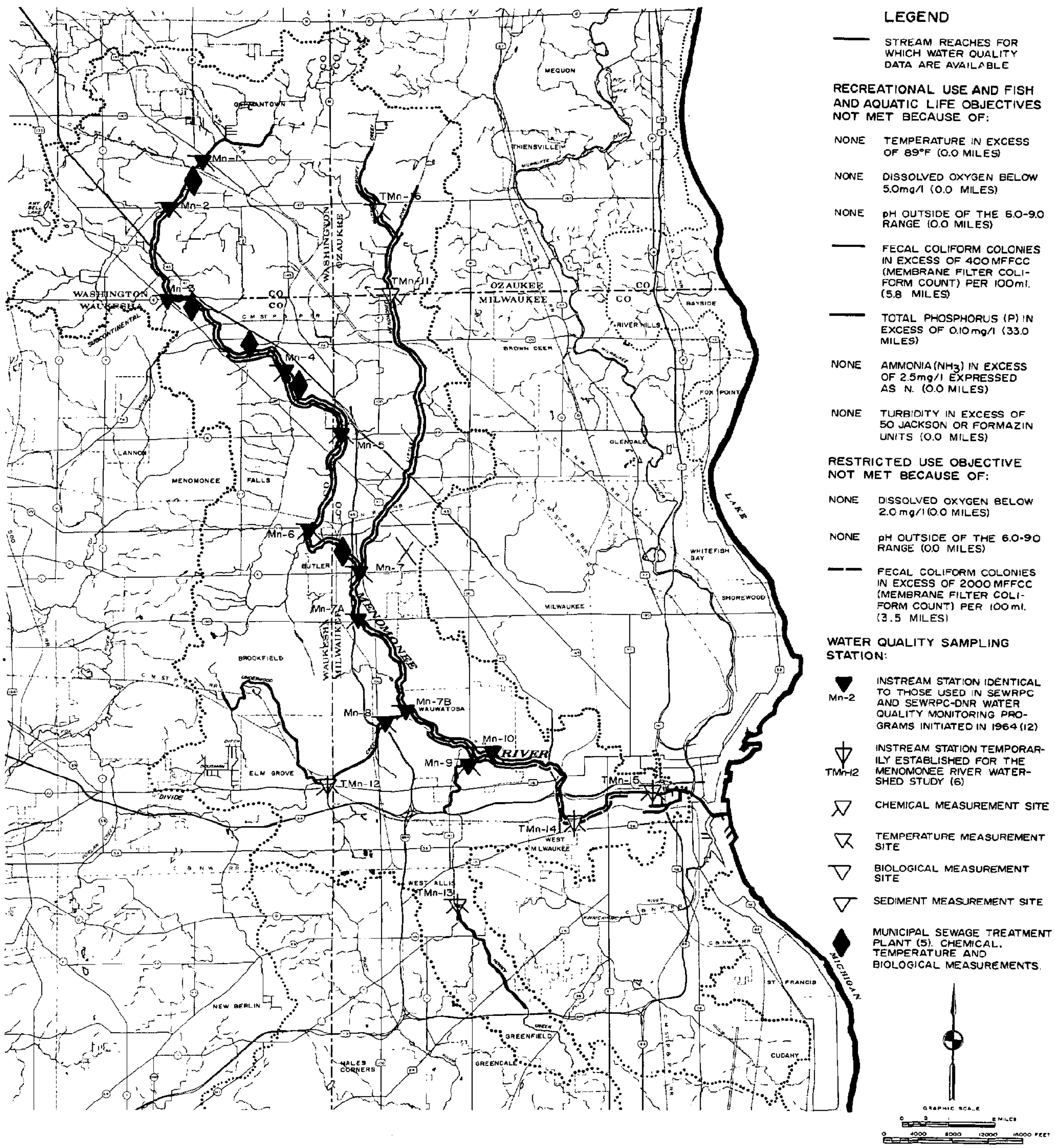
Figure 62 (continued)



Source: U. S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

Map 70

COMPARISON OF APRIL 4, 1973, SURFACE WATER QUALITY IN THE MENOMONEE RIVER WATERSHED TO ADOPTED WATER QUALITY STANDARDS



A comparison of the surface water quality in the Menomonee River watershed on April 4, 1973 to the adopted water quality standards indicated that the standards for fecal coliform and total phosphorus were exceeded in parts of the watershed.

Source: SEWRPC.

was being added to the stream system by the municipal sewage treatment plants at a rate of about 240 pounds per day during Synoptic Survey 1 while it was being carried from the watershed by the Menomonee River at twice that rate—approximately 480 pounds per day. Similarly, total nitrogen was discharged from the treatment facilities at a rate of about 350 pounds per day during Synoptic Survey 1 while it was transported from the watershed at about 3,700 pounds per day—over 10 times the rate of inflow from the sewage treatment supplies. The total phosphorus and total nitrogen transport data suggest the importance of diffuse sources in constructing a mass balance of these two nutrients during high flow-land surface runoff conditions.

Synoptic Survey 2: With respect to those stream reaches intended for recreational use and fish preservation of fish and aquatic life, Map 71 indicates that water quality conditions during Synoptic Survey 2 were such that the temperature, pH, and ammonia standards were satisfied throughout the watershed while substandard levels of dissolved oxygen, fecal coliform, and total phosphorus were recorded. Substandard dissolved oxygen concentrations—less than 5.0 mg/l—occurred along the main stem of the Menomonee River downstream of the Washington-Waukesha County line and along the entire length of the Little Menomonee River. These low oxygen levels generally occurred in the early morning hours and appear to reflect the low point in the diurnal oxygen pattern brought about by the nighttime respiration of algae and aquatic plants.

The fecal coliform bacteria standard of 400 colonies per 100 ml was exceeded only along the upper reaches of the main stem of the Menomonee River in the vicinity of the Village of Germantown and the Village of Menomonee Falls. In light of the absence of land surface runoff during this survey, these high fecal coliform concentrations may be caused by such sources as septic system discharge and inadvertent discharge of raw or inadequately treated sanitary sewage from municipal sewerage systems. Although it is not possible to pinpoint the source of the potential pathogenic pollution, the problem may not be attributed to the Menomonee Falls Pilgrim Road sewage treatment plant, since the effluent from this facility contained an average fecal coliform bacteria level of less than 100 colonies per 100 ml as indicated in Table 42. Similar data are not available for the other three municipal treatment facilities within or upstream of the reach containing excessive fecal coliform bacteria.

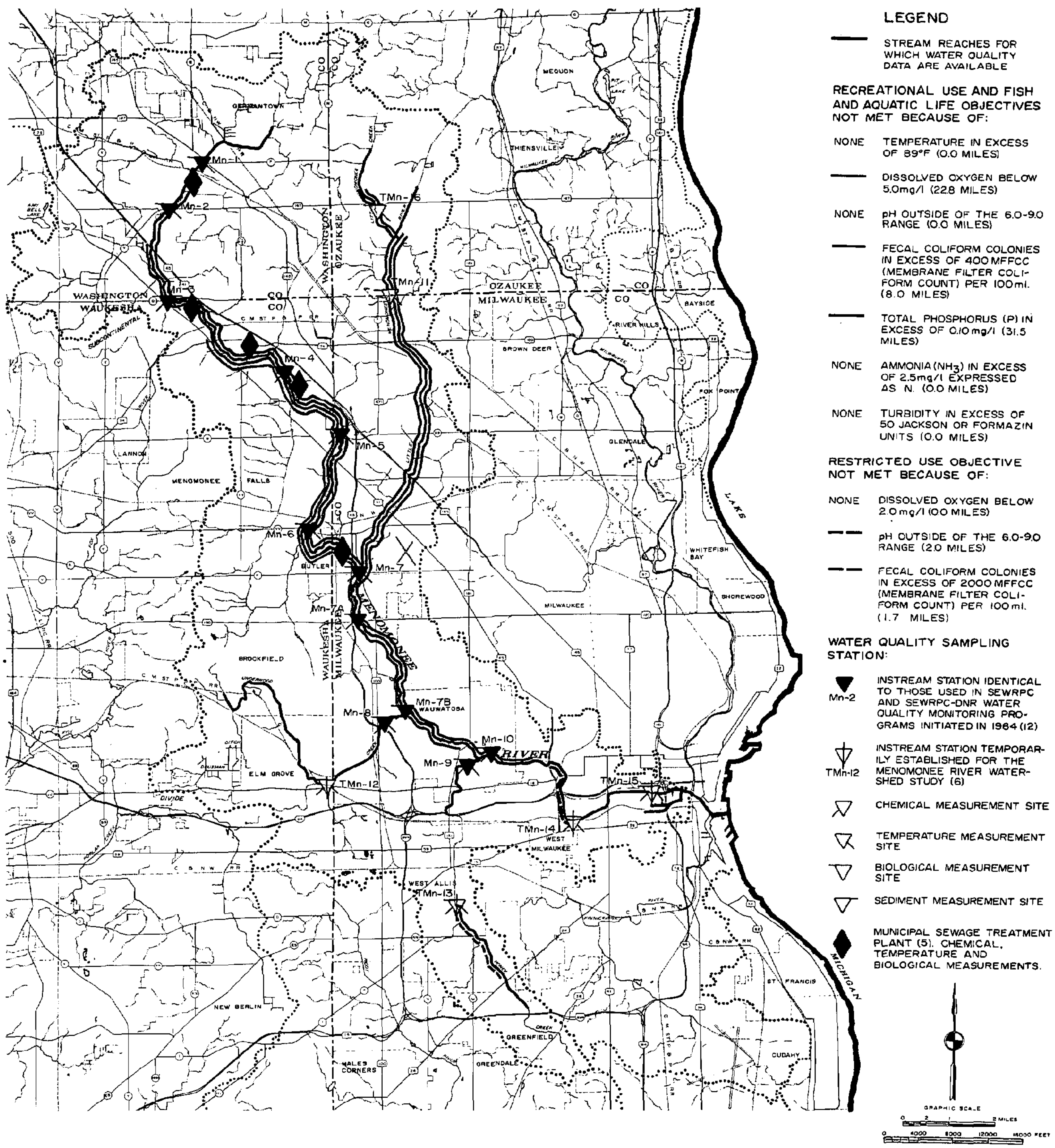
As was the case during Synoptic Survey 1, concentrations of the sixth parameter, total phosphorus, exceeded the recreational use and fish and aquatic life standard of 0.10 mg/l throughout most of the length of the Menomonee River designated for those uses and along most of the Little Menomonee River and Little Menomonee Creek which are also designated for those uses. Total phosphorus levels in excess of 0.10 mg/l on the main stem of the Menomonee River may be attributed, in part, to the discharge of this nutrient from the five municipal sewage treatment facilities located on the river during Synoptic Survey 2. The average total phosphorus concentrations in the Village of Germantown Old Village and County Line plants, the Village of Menomonee Falls Pilgrim Road and Lilly Road plants, and the Village of Butler facility were 8.2, 5.7, 5.2, 4.9, and 3.7 mg/l, respectively, during Synoptic Survey 2. The existence of high total phosphorus levels during dry, low flow periods—no precipitation occurred during Synoptic Survey 2 or on any of the seven days preceding it—on stream reaches not influenced by sewage treatment plant discharges or other known point sources of phosphorus suggests that the sustaining groundwater discharge to the streams contains phosphorus in excess of the standards. The phosphorus may enter the groundwater from septic systems or from the application of fertilizers in rural and urban areas. It is also possible that daily feedlot runoff contributes to the low flow phosphorus levels in headwater areas of the watershed.

Only dissolved oxygen, pH, and fecal coliform standards are applicable to those stream reaches for which the restricted use objective has been adopted. Surface water quality in all of these stream reaches met the dissolved oxygen standard. The pH standard which requires that pH be no less than 6.0 standard units and no more than 9.0 standard units was exceeded an insignificant amount at the Honey Creek station near the Milwaukee County McCarty Park. As was the case with Synoptic Survey 1, fecal coliform bacteria in excess of the standard of 2,000 colonies per 100 ml were found along the Menomonee River between the Hawley Road bridge and the estuary. The cause of these high bacterial counts is not apparent, inasmuch as this location is very far downstream of municipal sewage treatment plants and since dry flow conditions not conducive to combined sewer overflows prevailed during the survey. It is of interest to note, however, that although precipitation did not occur during Synoptic Survey 2 or on the seven days preceding the survey, a discharge from the Hawley Road outfall was observed and fecal coliform bacteria analyses performed on two samples revealed bacterial concentrations of 830,000 and 6,400,000 colonies per 100 ml.

Mass balances of selected constituents under low flow conditions such as those existing during Synoptic Survey 2 were found to differ markedly from those for high flow-land surface runoff conditions. Consider the conservative substance chloride, for example. The rate of discharge of chloride from the five municipal sewage treatment plants to the Menomonee River during Synoptic Survey 2 was estimated at 6,300 pounds per day, or about 40 percent of the rate at which it was being carried from the watershed by the Menomonee River at N. 70th Street in Wauwatosa. Under the high flow-land surface runoff conditions of Synoptic Survey 1, the sewage treatment plants accounted for only 7 percent of the mass flow of chloride in the Menomonee River near the watershed outlet. During Synoptic Survey 2, municipal sewage treatment facilities were discharging total phosphorus at a rate of about 140 pounds per day while it was leaving the watershed via the Menomonee River at only about 40 pounds per day—29 percent of the input rate. Similarly, total nitrogen was being added by the treatment plants at a rate of about 340 pounds per day while

Map 71

COMPARISON OF JULY 18, 1973 SURFACE WATER QUALITY IN THE MENOMONEE RIVER WATERSHED TO ADOPTED WATER QUALITY STANDARDS



A comparison of the surface water quality in the Menomonee River watershed on July 18, 1973—a day representative of dry weather conditions—to the adopted water quality standards indicated that the standards for dissolved oxygen, fecal coliform bacteria, and total phosphorus were exceeded in much of the watershed stream system. The grossly polluted condition of the stream system was caused by low stream flows and therefore lessened dilution potential, in combination with the pollutant contributions from sources such as sewage treatment plant discharges and inflow of shallow groundwater and possibly flow from animal feedlots and improperly functioning septic tank systems.

Source: SEWRPC.

being transported from the basin at about 260 pounds per day, or 76 percent the input rate. This excess of nutrient inflow over outflow suggests that the watershed stream system can function as a sink during low flow periods with the nutrients being used by algae and aquatic plants or being deposited with undissolved solids on the channel bottom. The channel bottom deposits may provide a source of nutrients during subsequent periods of high flow when some of the settled sediment is resuspended and carried from the watershed.

Synoptic Survey 3: Map 72 indicates that the temperature, pH, and ammonia standards were satisfied throughout the watershed during Synoptic Survey 3 for those portions of the watershed stream system intended for recreational use and for protection of fish and aquatic life. Substandard dissolved oxygen levels occurred along the upper Menomonee River and the lower portion of the Little Menomonee River. The fecal coliform bacteria standard of 400 colonies per 100 ml was exceeded along almost the entire length of the Menomonee River as well as along much of the Little Menomonee River and Little Menomonee Creek. The possible causes of excessive fecal coliform bacteria in the main stem of the Menomonee River are septic system discharges, and inadvertent discharge of raw or inadequately treated sanitary sewage from municipal sewerage systems, and feedlot discharge. As indicated in Table 42, effluent fecal coliform data are available only for the Germantown Old Village sewage treatment plant and the Menomonee Falls Lilly Road facility and, inasmuch as effluent concentrations did not exceed 40 colonies per 100 ml, these facilities do not appear to be a principal cause of the high instream fecal coliform bacteria levels. High fecal coliform concentrations in the Little Menomonee River and Little Menomonee Creek may be due to causes such as septic system discharge and feedlot discharge.

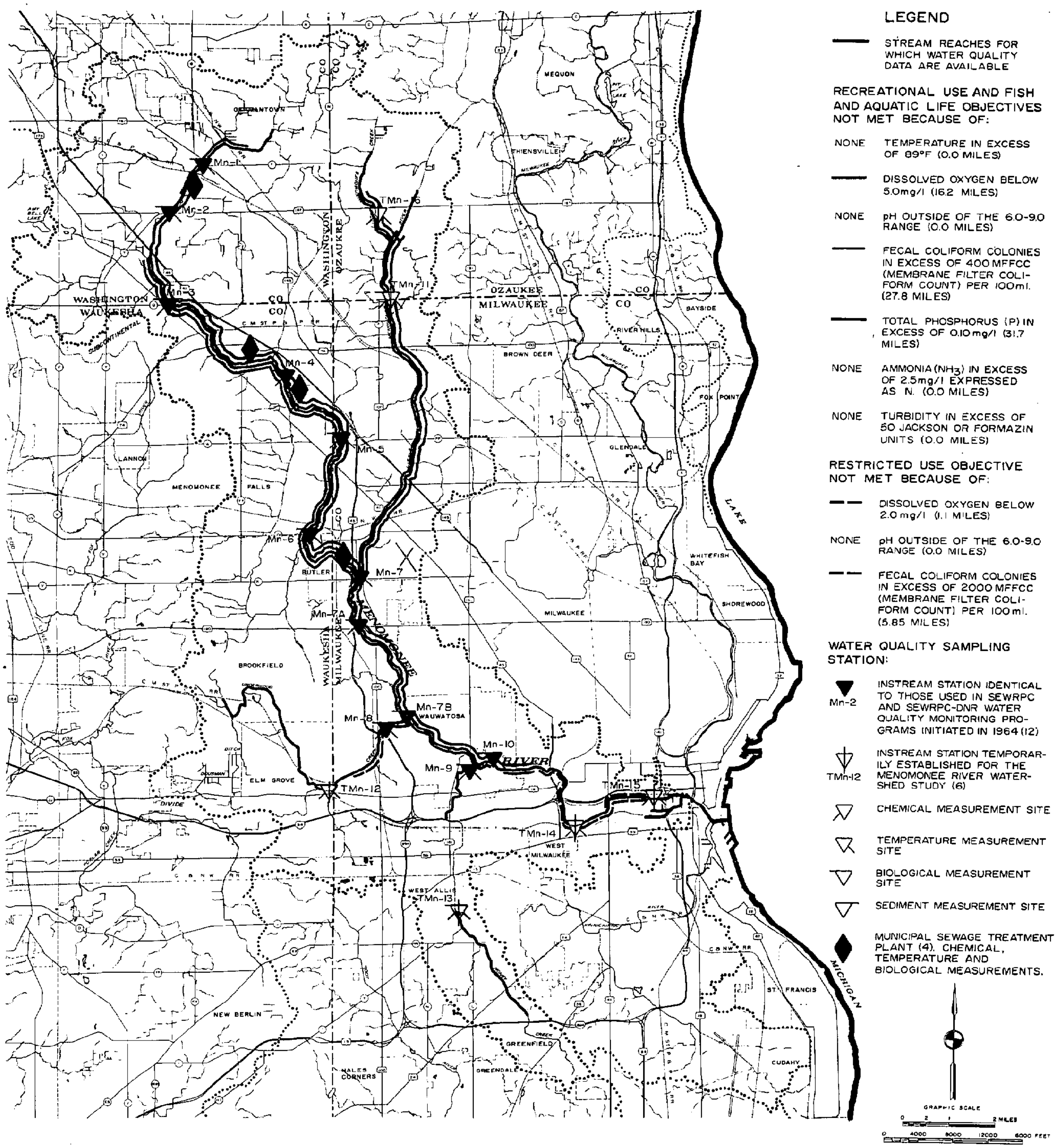
Total phosphorus concentrations were in excess of the recreation use and fish and aquatic life use standard of 0.10 mg/l throughout the entire length of the Menomonee River designated for those uses as well as along all of the Little Menomonee River and Little Menomonee Creek which are also designated for those uses. High total phosphorus levels along the main stem of the Menomonee River are due in part to phosphorus being discharged by four municipal sewage treatment facilities into the River. For example, the average concentrations of total phosphorus in the effluent of the Germantown Old Village plant, the Menomonee Falls Pilgrim Road plant, the Menomonee Falls Lilly Road plant, and the Butler overflow-chlorination facility were 9.3, 3.1, 2.3, and 11.7 mg/l, respectively, during Synoptic Survey 3. It is estimated that sewage treatment plant discharge accounted for at least 28 percent of the Menomonee River streamflow at the Wauwatosa gaging station during Synoptic Survey 3 and therefore the high—relative to the 0.10 mg/l instream standard—sewage treatment plant effluent phosphorus concentrations could easily account for the excessive phosphorus levels in the Menomonee River. As was the case in Synoptic Survey 2, substandard total phosphorus levels on the Little Menomonee River and Little Menomonee Creek appear to be due to excessive phosphorus concentrations in the groundwater being discharged to the streams. Possible means by which that phosphorus enters the groundwater system include onsite waste disposal systems and agricultural and residential application of fertilizers. Feedlot discharge may also contribute phosphorus to the surface waters during low flow periods.

Only dissolved oxygen, pH, and fecal coliform are applicable to those stream reaches for which the restricted water use objective has been adopted. Although the pH standards was met in all of those stream reaches during Synoptic Survey 3, Map 72 indicates that the dissolved oxygen standard of a minimum of 2.0 mg/l was not satisfied in the estuary area of the Menomonee River. In addition, the maximum fecal coliform bacteria limit of 2,000 colonies per 100 ml was exceeded along the main stem of the Menomonee River downstream of the Hawley Road crossing and along the lower portion of Underwood Creek. While the low dissolved oxygen levels in the estuary appear to be due to diurnal fluctuations superimposed on low overall oxygen reserves, the cause of excessive fecal coliform counts on the lower Menomonee River and the lower reaches of Underwood Creek is not readily explained. Of interest is an occurrence similar to that which occurred during Synoptic Survey 2: although no precipitation occurred during the day of Synoptic Survey 3 or on the preceding day, a discharge was observed from the Hawley Road combined sewer, and two fecal coliform analyses of that flow revealed bacterial concentrations of 590 and 5,400 colonies per 100 ml. This suggests that combined sewer outfalls may discharge fecal coliform bacteria and other pollutants to the stream system during dry, low flow periods. The flow may be infiltrating groundwater, and the source of the bacteria and other pollutants may be deposits on the invert of the outfall sewer.

An examination of the mass flows of selected constituents for Synoptic Survey 3 provides additional insight into low flow water quality relationships. The conservative substance chloride was discharged to the Menomonee River from the five municipal sewage treatment plants at an estimated rate of 6,500 pounds per day while it was being transported from the watershed by the Menomonee River at N. 70th Street in Wauwatosa at a rate of about 14,000 pounds per day. Therefore the discharges of the treatment plants accounted for 47 percent of the chloride being carried from the basin during these low flow conditions whereas they accounted for only 7 percent of the chloride leaving the watershed under the high flow-land surface runoff conditions that existed during Synoptic Survey 1. During Synoptic Survey 3, total phosphorus was discharged from the municipal sewage treatment plants at a rate of approximately 60 pounds per day while it was leaving the watershed via the Menomonee River at only two-thirds of that rate—about 40 pounds per day. Similarly, total nitrogen was being added to the stream system by the treatment plants at approximately 350 pounds per day while it was being transported from the watershed at about 200 pounds per day—about 57 percent the inflow rate from treatment plants. This low flow condition nutrient imbalance is similar to that which occurred during Synoptic Survey 3 and probably reflects the uptake of nutrients by algae and aquatic plants and the settling out of solids containing nutrients.

Map 72

COMPARISON OF AUGUST 6, 1974, SURFACE WATER QUALITY IN THE MENOMONEE RIVER WATERSHED TO ADOPTED WATER QUALITY STANDARDS



A comparison of the surface water quality in the Menomonee River watershed on August 5, 1974—a day representative of dry weather conditions—to the adopted water quality standards indicated that the standards for fecal coliform bacteria and total phosphorus were exceeded in much of the watershed stream system. High bacteria and phosphorus levels along the Little Menomonee River probably represent the net effect of sources such as improperly functioning septic systems, flow from animal feedlots, and inflow of shallow groundwater. Excessive bacteria and phosphorus concentrations on the main stem of the Menomonee River are attributable to the above sources plus treated effluent from four municipal sewage treatment plants.

Source: SEWRPC.

GROUNDWATER QUALITY AND POLLUTION

The natural environment of the watershed has been, to date, a far more important determinant of groundwater quality than have the effects of human activities within the watershed. The groundwater resources, in contrast to the surface water resources, are not so readily subject to contamination from urban and rural runoff and waste discharges. As indicated in Chapter III of this volume, three major aquifers underlie the Menomonee River watershed. In order from land surface downward, they are: 1) the sand and gravel deposits in the glacial drift; 2) the shallow dolomite strata in the underlying bedrock; and 3) the deeper sandstone, dolomite, siltstone, and shale strata. Because of their relative nearness to the land surface and because of their interconnection, the first two aquifers are commonly referred to collectively as the "shallow aquifer," while the latter is referred to as the "deep aquifer." The aquifers are normally supplied with water from zones known as recharge areas. The shallow aquifers in the Menomonee River watershed are recharged locally by direct rainfall or by stream or wetland water entering the ground through recharge areas of porous soil or rock directly overlying the aquifer. The deep aquifer is recharged by stream, wetland, or lake water or direct rainfall entering the ground through recharge areas lying west of the watershed where the relatively impervious Maquoketa shale, which separates the deep aquifer from the shallow aquifer, is absent.

Groundwater Quality

Sources of Dissolved Constituents: The amount and kind of dissolved minerals in groundwater differ greatly throughout the watershed and depend upon such factors as the amount and type of organic material in the soil; the solubility of rock over or through which the water moves; the length of time the groundwater is in contact with the soil and rock; and the temperature and pH of the water. Some kinds of rock contain highly soluble minerals, and groundwater contained in or passing through such rock will become highly mineralized. Other kinds of rock, however, consist of relatively insoluble minerals which impart relatively small amounts of mineralization to groundwater. The principal sources of these substances, as present in groundwater, are summarized in Table 59. For a more complete discussion of these chemical substances and properties, see SEWRPC Technical Report No. 4, Water Quality and Flow of Streams in Southeastern Wisconsin, 1966.

During periods of base—or low—flow, stream water quality in most of the watershed may be expected to be similar to the quality of shallow groundwater in terms of dissolved mineral content. This is to be expected because at base flow most of the stream water results from groundwater seepage. The range of concentrations of dissolved substances, however, is often less in surface water during low flow conditions than in groundwater, due to the mixing action afforded during groundwater seepage into the stream from various sources and the precipitation of dissolved minerals in the stream.

Chemical Quality of Groundwater Related to Water Use: The natural chemical and physical characteristics of the groundwater supplies are extremely important to domestic, municipal, and industrial water users. The quality of groundwater in the Menomonee River basin generally is good, and the water is suitable for most uses. High concentrations of certain dissolved substances, however, are present in all three aquifers and may limit the use of groundwater from these aquifers for some purposes.

Because untreated groundwater is used to meet domestic water needs in the northern and western portions of the watershed, it must also be safe in its natural condition for human consumption. Safe limits for concentrations of mineral substances in drinking water are difficult to establish because of the wide range of tolerance and consumption among individuals. Maximum allowable upper limits for substances in drinking water, as listed in Table 61, have been established by the Wisconsin Department of Natural Resources[38] and U. S. Environmental Protection Agency[39] because some of them are relatively toxic in very small concentrations. Standards for other likely major uses of groundwater recommended by the Regional Planning Commission are listed in Table 60. For a discussion of the origin of these standards, refer to SEWRPC Technical Report No. 4, Water Quality and Flow of Streams in Southeastern Wisconsin, Chapter III, 1966.

The presence of any of the substances listed in Table 61 in concentrations exceeding the maximum allowable limits constitutes a basis for rejecting the water. With the exceptions of iron, manganese, and sulfate, most of these substances are rare in the groundwater drawn from aquifers in the Menomonee River watershed. Table 61 places the various chemical substances that may be contained in the water and properties of the water furnished to the consumers into two categories based on physiological or aesthetic conditions. At concentrations exceeding the maximum allowable limits, those substances in the aesthetic category may impart undesirable tastes, colors, or odors to the drinking water. Water with chemical substances in the aesthetic category exceeding the maximum allowable limits is used for drinking in many areas without any apparent ill effects.

The water quality standards set forth in Tables 60 and 61 serve as a basis for the subsequent analysis of groundwater quality in the watershed.

Groundwater Quality by Aquifer: Groundwater quality data for 123 wells in and near the Menomonee River watershed were assembled and collated under the watershed planning program and used to evaluate groundwater quality. Map 73 shows the location of these wells and indicates the aquifer or aquifers that each well taps. A total of five of the wells tap the sand and gravel aquifer, 73 tap the dolomite aquifer, 22 are open to only the sandstone aquifer, and 23 are open to both the dolomite

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[38] *Wis. Adm. Code NR 111 (1974), pp. 40h-40j.*

[39] *"Water Programs," The Federal Register, part 4, Washington, D. C., Dec. 24, 1975.*

Table 59

SOURCES OF SELECTED GROUNDWATER CONSTITUENTS

Constituent or Property	Source
Silica (SiO_2)	Chemical breakdown of silicate minerals during weathering.
Iron (Fe)	Dissolved from practically all rocks, soils, well casings, pipes, and storage tanks.
Manganese (Mn)	Dissolved from soils and clay minerals.
Calcium (Ca) and Magnesium (Mg)	Dissolved from practically all soils and rocks but especially from limestone, dolomite, and gypsum.
Sodium (Na) and Potassium (K)	Dissolved from practically all types of rocks and soils. Also present in sea water, industrial wastes, and sewage.
Bicarbonate (HCO_3) and Carbonate (CO_3)	Interaction of dissolved carbon dioxide and water on carbonate rocks such as limestone and dolomite. Decomposition of organic matter.
Sulfate (SO_4)	Dissolved from rocks and soils containing iron sulfide, gypsum, and other sulfur compounds. Sulfate reduction by bacteria. Present in sea water, precipitation, and some industrial wastes.
Chloride (Cl)	Dissolved from rocks and soils. Principal ion in sea water. Present in industrial wastes and sewage.
Fluoride (F)	Dissolved from rocks and soils containing fluoride bearing minerals.
Nitrate (NO_3) and Nitrite (NO_2)	Formed by bacterial action in soils and plants. Concentrated in plant and animal wastes, fertilizers, sewage, and septic tank effluent. Nitrate is also present in precipitation.
Dissolved Solids	Chiefly inorganic mineral constituents dissolved in water but also includes organic constituents.
Hardness as $CaCO_3$	Nearly all hardness is due to calcium and magnesium ions in water that are dissolved from soils and carbonate rocks.
Alkalinity	Caused by all negative ions (anions) entering into hydrolysis reactions. These are chiefly bicarbonate, carbonate, and hydroxide.
Hydrogen Ion Concentration (pH)	Caused by the excess or deficiency of hydrogen ions in a solution.

Source: U. S. Geological Survey.

and sandstone aquifer. A large amount of representative data is available for the dolomite aquifer in that most of the wells—59 percent of the total—tap that aquifer and those wells are distributed rather uniformly over the watershed and contiguous areas. Fewer of the wells tap the sand and gravel aquifer and the sandstone aquifer, and these are not so uniformly distributed over the watershed as are the dolomite aquifer wells.

The Sand and Gravel Aquifer: Results of chemical analyses of five water quality samples from five sample wells in the sand and gravel aquifer collected during the period June 11, 1974, to June 14, 1974, are summarized in Table 62. Some of the samples taken from wells tapping the sand and gravel aquifer contain substances in concentrations exceeding the limits set forth in Table 61. Percentages of sand and gravel aquifer samples exceeding the maximum allowable standards for drinking water are shown in Table 63. The table does not include all the water quality parameters appearing in Table 61 in that it is limited only to those parameters in the standards for which water quality data are available. The sulfate, chloride, fluoride, and nitrate standards were not exceeded in any of the five samples. The sand and gravel aquifer appears to yield water with a relatively high iron and perhaps a relatively high manganese concentration. Four of the five samples contained iron in excess of the 0.3 mg/l standard while two of the five samples exhibited manganese in excess of the recommended level of 0.05 mg/l. Iron concentrations ranged from 0.04 to 1.60 mg/l and averaged 0.77 mg/l whereas manganese concentrations ranged from 0.02 to 0.12 mg/l with a mean of 0.05 mg/l.

Table 60

WATER QUALITY STANDARDS FOR MAJOR WATER USES RECOMMENDED BY THE SEWRPC[a]

Parameter[b]	Industrial Water Supply														Livestock and Wildlife Watering	Irrigation
	Baking	Boiler Feed (Pressure in PSI)				Brewing	Carbonated Beverages	Dairy Industry	Food Canning and Freezing	Food Equipment Washing	Industrial Process Water (General)	Laundering	Tanning	Cooling		
		0-150	150-250	250-400	400											
Silica	--	40	20	5	1	50	--	--	--	--	--	--	--	--	--	--
Iron	0.2	--	--	--	--	0.1	0.2	0.3	0.2	0.2	0.2	0.2-1.0	2.0	0.5	--	--
Manganese	0.2	--	--	--	--	0.1	0.2	0.1	0.2	--	0.1	0.2	0.2	0.5	--	--
Chromium (Hex.)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Calcium	--	--	--	--	--	100-500	--	--	--	--	--	--	--	--	--	--
Magnesium	--	--	--	--	--	30	--	--	--	--	--	--	--	--	--	--
Sodium	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bicarbonate	--	50^c	30^c	5^c	0^c	--	--	--	--	--	--	--	--	--	--	--
Carbonate	--	200	100	40	20	50-68	--	--	--	--	--	--	--	--	--	--
Sulfate	--	--	--	--	--	--	250	60	--	--	--	--	--	--	--	--
Chloride	--	--	--	--	--	60-100	250	30	--	250	250	--	--	--	1,500	--
Fluoride	--	--	--	--	--	1.0	1.0	--	1.0	1.0	--	--	--	--	--	--
Nitrite	--	--	--	--	--	0	--	0	--	--	--	--	--	--	--	--
Nitrate	--	--	--	--	--	10^d	--	30	15	--	--	--	--	--	--	--
Phosphorus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyanide	--	--	--	--	--	--	--	--	--	--	--	--	-	--	--	--
Oil	--	--	--	--	--	0	--	--	--	--	--	--	--	--	--	--
Detergents	--	--	--	--	--	--	--	--	--	--	1.0	--	--	--	--	--
Dissolved Solids	--	--	--	--	--	500-1500	850	--	850	850	750	--	--	--	7,000	2,000
Hardness	--	80	40	10	2	--	250	180	75-400	10	--	50	513	1,000	--	--
Alkalinity (Total)	--	--	--	--	--	75-150	128	--	--	--	--	60	135	--	--	--
pH	--	8.0M	8.4M	9.0M	9.6M	6.5-7.0	--	--	7.5M	--	5.0-9.0	6.0-6.8	6.0-8.0	5.0-9.0	5.0-9.0	--
Specific Conductance	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Color	10	80	40	5	2	10	10	0	--	20	50	--	100	--	--	3,000
Turbidity	10	20	10	5	1	10	2	--	10	1.0	250	--	20	50	--	--
Biochemical Oxygen Demand	--	--	--	--	--	--	--	--	--	--	10	--	--	--	--	--
Dissolved Oxygen	--	2.0^c	0.2^c	0.0^c	0.0^c	--	--	--	--	--	1.0M	--	--	--	--	--
Coliform Count	--	--	--	--	--	--	--	100	1	1	5,000	--	--	--	--	--
Temperature (°F)	--	--	--	--	--	--	--	--	--	--	80	--	--	90	--	--

[a] *Water quality standards set forth in SEWRPC Technical Report No. 4, Water Quality and Flow of Streams in Southeastern Wisconsin, November 1966. Limits are recommended maximum or maximum permissible values.*

[b] *The limiting values of the chemical, physical, biochemical, and bacteriological parameters are expressed in PPM (mg/l) except pH, specific conductance, color, turbidity, coliform count, and temperature.*

[c] *Limits applicable only to feed water entering boiler, not to original water supply.*

[d] *Nitrate as NO_3-N.*

Source: SEWRPC.

In summary, of the six parameters for which drinking water standards have been established and data are available—iron, manganese, sulfate, chloride, fluoride, and nitrate—water drawn from the sand and gravel aquifer is very likely to contain excessive iron concentrations and perhaps substandard manganese levels while the water generally conforms to drinking water standards for the remaining four parameters.

Hardness analyses conducted on the five samples yielded values ranging from 240 to 530 mg/l with an average of 348 mg/l. This water would be considered "hard" for general domestic use and for some industrial-commercial uses.

Dolomite Aquifer: Table 64 summarizes the results of the analyses of 86 water quality samples collected from 73 sample wells open to the dolomite aquifer during the period July 26, 1945, to June 14, 1974. Percentages of dolomite aquifer samples exceeding the recommended drinking water standards are shown in Table 63.

The chloride and fluoride standards were not exceeded in any of the 85 available samples. Similarly, there were no instances of excessive nitrate in any of the samples. Sulfate was in excess of the standard in 11 percent of the samples. Very high iron and manganese levels occur in water from the dolomite aquifer in that 44 percent of the 84 iron analyses were in excess of the recommended 0.3 mg/l

Table 61

WISCONSIN DEPARTMENT OF NATURAL RESOURCES DRINKING WATER STANDARDS

Chemical Constituent	Maximum Allowable Upper Limit (mg/l except as noted)	Type of Limit
Arsenic	0.1	Health
Barium	1.0	Health
Cadmium[a]	0.01	Health
Chloride	250	Aesthetics
Chromium[a]	0.05	Health
Color	15 Units	Aesthetics
Copper[a]	1.0	Aesthetics
Cyanide	0.2	Health
Fluoride	2.4	Health[b]
Foaming Agents		
(Methylene-Blue Active Substances)	0.5	Aesthetics
Iron[a]	0.3	Aesthetics
Lead[a]	0.05	Health
Manganese[a]	0.05	Health
Mercury[a]	0.002	Health
Nitrate as (NO_3)	45	Health
Odor	3 (Threshold No.)	Aesthetics
Organics-Carbon Adsorbable		
CCE_m (Carbon Chloroform Extract)	0.7	Health[c]
CAE_m (Carbon Alcohol Extract)	3.0	Health
Pesticides		
(A) Chlorinated Hydrocarbon Insecticides,		
Aldrin	0.001	Health
Chlordane	0.003	Health
DDT	0.05	Health
Dieldrin	0.001	Health
Endrin	0.0005	Health
Heptachlor	0.001	Health
Heptachlor Epoxide	0.0001	Health
Lindane	0.005	Health
Methoxychlor	0.1	Health
Toxaphene	0.005	Health
(B) Organophosphate Insecticides		
Parathion	0.1	Health
(C) Chlorophenoxy Herbicides		
2,4-D	0.02	Health
2,4,5-TP	0.03	Health
Selenium	0.01	Health
Silver[a]	0.05	Health
Sodium	No limit designated[d]	--
Sulfate	250	Aesthetics
Turbidity	1TU	Health[e]
Zinc[a]	5	Aesthetics

[a] *Heavy metal.*

[b] *Natural fluoride concentrations exceeding 2.4 mg/l may be allowed in water if dental fluorosis is not a significant factor.*

[c] *The subscript "m" denotes determination by miniaturized sampler and extraction technique.*

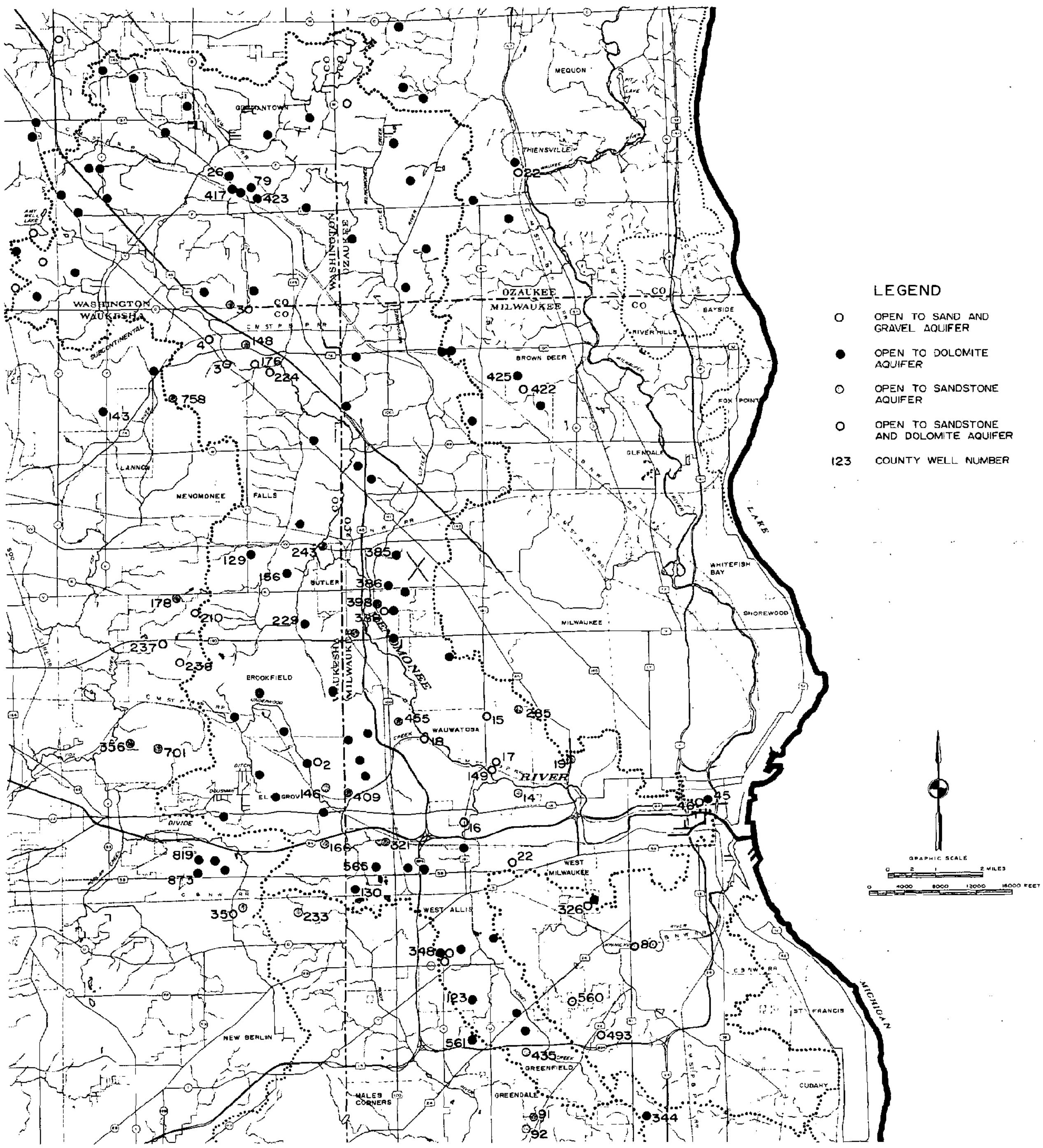
[d] *The water works owner should periodically notify local physicians of the sodium content of the water supply in order that the physicians may advise their patients of suitable dietary restrictions.*

[e] *Turbidity shall not exceed one unit except where it can be demonstrated that a higher turbidity not exceeding five units does not interfere with disinfection, cause tastes or odors upon disinfection, prevent the maintenance of an effective disinfection agent throughout the distribution system, result in deposits in the distribution system, or cause consumers to question the safety of their drinking water.*

Source: *Wisconsin Department of Natural Resources.*

Map 73

LOCATION OF U. S. GEOLOGICAL SURVEY GROUNDWATER QUALITY SAMPLING WELLS IN THE MENOMONEE RIVER WATERSHED AND ENVIRONS



Groundwater quality data were assembled and collated under the watershed planning program for over 123 wells located in and near the Menomonee River watershed and used to evaluate groundwater quality. A total of five of the wells tap the sand and gravel aquifer, 73 tap the dolomite aquifer, 22 are open to only the sandstone aquifer, and 23 are open to both the dolomite and sandstone aquifer.

Source: U. S. Geological Survey and SEWRPC.

Table 62

CHEMICAL ANALYSIS OF GROUNDWATER FROM THE SAND AND GRAVEL AQUIFER IN THE MENOMONEE RIVER WATERSHED

USGS No.	County	Owner	Location	Depth of Well (feet)	Elevation of Bottom (feet-msl)	Date of Collection	Groundwater Quality Parameters[a] Iron[b] (Fe)	Manganese[b] (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate[b] (SO_4)	Chloride[b] (Cl)	Fluoride[b] (F)	Nitrate[b] (NO_3)	Nitrite (NO_2)	Dissolved Solids	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	pH (field)
105	Ozaukee	Private	T9N, R21E, Section 7	--[c]	--[c]	6/11/74	0.75	0.03	49	41	12.0	344	46	1.8	0.5	0.09	0.0	352	290	282	7.7
162	Washington	Private	T9N, R20E, Section 6	--[c]	--[c]	6/14/74	0.35	0.03	43	32	11.0	315	1	1.1	0.4	0.09	0.0	251	240	258	7.8
155	Washington	Private	T9N, R19E, Section 36	--[c]	--[c]	6/13/74	0.04	0.02	120	55	6.1	473	48	45.0	0.2	44.00	0.0	657	530	388	7.2
167	Washington	Private	T9N, R19E, Section 25	--[c]	--[c]	6/13/74	1.10	0.12	92	43	4.3	395	60	15.0	0.1	0.00	0.0	487	410	324	7.5
180	Washington	Private	T9N, R19E, Section 25	--[c]	--[c]	6/14/74	1.60	0.06	53	33	9.1	314	15	1.6	0.8	0.09	0.0	275	270	258	7.8
						Minimum	0.04	0.02	43	32	4.3	314	1	1.1	0.1	0.00	0.0	251	240	258	7.2
						Mean	0.77	0.05	71	41	8.5	368	34	12.9	0.4	8.85	0.0	404	348	302	7.6
						Maximum	1.60	0.12	120	55	12.0	473	60	45.0	0.8	44.00	0.0	657	530	388	7.8

[a] *Analyses in mg/l except pH, which is in standard units.*

[b] *Parameters for which Wisconsin Department of Natural Resources drinking water standards are available.*

[c] *Not available.*

Source: U. S. Geological Survey and SEWRPC.

Table 63

PERCENT OF GROUNDWATER SAMPLES IN THE MENOMONEE RIVER WATERSHED EXCEEDING WISCONSIN DEPARTMENT OF NATURAL RESOURCES DRINKING WATER STANDARDS

Aquifer	Iron (Fe) Number of Samples	Iron (Fe) Samples Exceeding Standard (0.3 mg/l) Number	Percent	Manganese (Mn) Number of Samples	Manganese (Mn) Samples Exceeding Standard (0.05 mg/l) Number	Percent	Iron (Fe) + Manganese (Mn) Number of Samples	Iron (Fe) + Manganese (Mn) Samples Exceeding Standard (0.35 mg/l)[a] Number	Percent
Sand and Gravel	5	4	80	5	2	40	--	--	--
Dolomite	84	37	44	64	52	81	--	--	--
Sandstone	--	--	--	--	--	--	53	42	79
Sandstone and Dolomite	--	--	--	--	--	--	38	18	47
Total	89	41	46	69	54	78	91	60	66

Aquifer	Sulfate (SO_4) Number of Samples	Sulfate (SO_4) Samples Exceeding Standard (250 mg/l) Number	Percent	Chloride (Cl) Number of Samples	Chloride (Cl) Samples Exceeding Standard (250 mg/l) Number	Percent	Fluoride (F) Number of Samples	Fluoride (F) Samples Exceeding Standard (2.4 mg/l) Number	Percent	Nitrate (NO_3) Number of Samples	Nitrate (NO_3) Samples Exceeding Standard (45 mg/l)[a] Number	Percent
Sand and Gravel	5	0	0	5	0	0	5	0	0	5	0	0
Dolomite	85	9	11	85	0	0	84	0	0	75	0	0
Sandstone	53	24	45	55	0	0	47	0	0	40	0	0
Sandstone and Dolomite	36	9	25	40	0	0	39	0	0	24	0	0
Total	179	42	23	85	0	0	175	0	0	144	0	0

[a] *Standard based on the sum of the iron standard of 0.3 mg/l and the manganese standard of 0.05 mg/l. Samples exceeding this value have iron and/or manganese concentrations exceeding their respective standard.*

Source: U. S. Geological Survey and SEWRPC.

Table 64

CHEMICAL ANALYSES OF GROUNDWATER FROM THE DOLOMITE AQUIFER IN THE MENOMONEE RIVER WATERSHED

USGS Well No.	County	Owner	Location	Depth of Well (feet)	Elevation of Bottom (feet-msl)	Date of Collection	Groundwater Quality Parameters[a] Iron[b] (Fe)	Manganese[b] (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate[b] (SO_4)	Chloride[b] (Cl)	Fluoride[b] (F)	Nitrate[b] (NO_3)	Nitrite (NO_2)	Dissolved Solids	Hardness as $CACO_3$	Alkalinity as $CACO_3$	pH (field)
79	Washington	Village of Germantown	T9N, R20E, Section 23	342	538	6/14/74	0.00	0.14	78.0	40	5.3	371	52	8.8	0.3	2.60	0.46	419	360	304	7.7
79	Washington	Village of Germantown	T9N, R20E, Section 23	342	538	7/29/66	0.59	--	150.0	38	4.7	327	240	2.1	0.5	1.80	--	670	523	--	7.8
79	Washington	Village of Germantown	T9N, R20E, Section 23	342	538	4/18/66	0.40	--	110.0	34	4.2	324	150	3.5	0.5	0.30	--	500	418	--	7.4
79	Washington	Village of Germantown	T9N, R20E, Section 23	342	538	12/6/64	0.12	--	160.0	47	--	312	320	5.0	0.8	--	--	--	580	--	7.6
79	Washington	Village of Germantown	T9N, R20E, Section 23	342	538	11/9/64	0.28	--	--	--	--	280	110	68.0	--	17.00	--	--	436	--	8.2
28	Washington	Hilltop Ready Mix	T9N, R20E, Section 19	322	645	6/13/74	0.00	0.18	79.0	43	7.7	380	48	24.0	0.2	4.20	0.00	453	370	312	7.3
37	Washington	Kennedy Middle School	T9N, R20E, Section 22	223	479	6/14/74	0.01	0.57	130.0	41	15.0	355	180	20.0	0.5	0.40	0.00	601	490	291	7.7
67	Washington	Richfield Elementary School	T9N, R19E, Section 13	300	715	6/14/74	0.01	0.00	83.0	43	5.1	366	36	31.0	0.2	15.00	0.00	506	380	300	7.5
152	Washington	Private	T9N, R20E, Section 20	213	717	6/13/74	0.33	0.82	88.0	50	22.0	383	50	97.0	0.2	0.22	0.03	948	430	314	7.4
154	Washington	Private	T9N, R20E, Section 5	172	753	6/13/74	0.13	0.57	46.0	27	17.0	268	27	1.6	0.3	0.09	0.00	266	230	220	7.8
158	Washington	Private	T9N, R20E, Section 31	188	687	6/13/74	0.58	0.43	77.0	37	3.4	386	28	2.9	0.2	0.00	0.00	376	340	317	7.4
159	Washington	Private	T9N, R20E, Section 8	217	665	6/13/74	0.06	0.14	100.0	42	3.8	371	120	4.3	0.3	0.53	0.03	514	420	304	7.4
160	Washington	Private	T9N, R19E, Section 36	242	658	6/13/74	0.28	0.67	79.0	40	3.0	417	22	3.4	0.2	0.09	0.03	366	360	342	7.4
162	Washington	Private	T9N, R20E, Section 6	170	740	6/14/74	0.35	0.29	43.0	32	11.0	315	1	1.1	0.4	0.09	0.00	251	240	258	7.8
164	Washington	Private	T9N, R20E, Section 9	180	705	6/13/74	0.00	0.14	84.0	44	13.0	365	52	27.0	0.2	30.00	0.03	550	390	299	7.4
167	Washington	Private	T9N, R19E, Section 25	123	922	6/13/74	1.10	1.20	92.0	43	4.3	395	60	15.0	0.1	0.00	0.00	487	410	324	7.5
172	Washington	Private	T9N, R20E, Section 19	142	858	6/13/74	0.29	0.27	76.0	38	4.7	374	46	11.0	0.2	1.30	0.00	403	350	307	7.5
176	Washington	Private	T9N, R20E, Section 24	220	679	6/13/74	0.15	2.00	48.0	44	8.5	352	19	1.0	0.4	0.04	0.00	306	300	289	7.6
180	Washington	Private	T9N, R19E, Section 25	241	754	6/14/74	1.60	0.57	53.0	33	9.1	314	15	1.6	0.8	0.09	0.00	275	270	258	7.8
181	Washington	Private	T9N, R20E, Section 14	100	770	6/13/74	0.18	0.14	32.0	32	20.0	239	50	2.7	0.6	0.04	0.69	278	210	196	8.0
187	Washington	Private	T9N, R20E, Section 18	190	735	6/14/74	0.00	0.14	93.0	43	7.5	380	74	19.0	0.2	9.30	0.00	483	410	312	7.3
197	Washington	Private	T9N, R19E, Section 25	202	853	6/13/74	1.60	0.27	75.0	40	5.8	405	19	7.5	0.2	0.04	0.00	368	350	332	7.5
199	Washington	Private	T9N, R20E, Section 16	225	785	6/14/74	0.00	0.43	54.0	42	4.7	353	21	2.9	0.2	0.62	0.03	328	310	290	7.5
202	Washington	Private	T9N, R20E, Section 18	154	646	6/14/74	0.00	0.14	96.0	50	15.0	418	54	43.0	0.2	22.00	0.03	550	450	343	7.2
155	Washington	Private	T9N, R19E, Section 36	60	950	6/13/74	0.04	0.18	120.0	55	6.1	473	48	45.0	0.2	44.00	0.03	657	530	388	7.2
67	Washington	Private	T9N, R19E, Section 13	313	782	6/14/74	0.01	0.14	98.0	52	12.0	366	56	71.0	0.1	29.00	0.82	570	460	300	7.2
26	Washington	Gehl Dairy	T9N, R20E, Section 22	232	638	7/11/62	0.15	--	3.6	--	--	359	59	3.0	0.1	2.10	--	376	348	--	7.3
417	Washington	Calvary United Methodist Church	T9N, R20E, Section 22	180	687	11/9/72	0.80	--	210.0	87	4.4	290	610	6.1	0.5	1.80	--	1,170	880	--	7.3
191	Washington	Private	T9N, R20E, Section 34	141	727	6/12/74	0.40	0.55	68.0	54	8.2	467	25	2.9	0.4	0.18	0.00	358	390	383	7.3
166	Washington	Private	T9N, R20E, Section 35	225	675	6/12/74	0.17	0.18	89.0	67	20.0	475	68	48.0	0.4	0.84	0.00	636	500	390	7.3
83	Ozaukee	Thiensville-Mequon School District 2	T9N, R21E, Section 27	455	257	6/12/74	0.07	0.09	130.0	32	22.0	219	300	2.3	0.9	0.89	0.00	677	460	180	7.4
92	Ozaukee	Riemer Mueller, Inc.	T9N, R21E, Section 32	171	554	6/10/74	0.19	0.00	19.0	18	27.0	179	34	1.1	0.8	0.40	0.76	216	120	147	8.1
101	Ozaukee	Foley Construction Company	T9N, R21E, Section 8	248	560	6/11/74	0.33	0.36	51.0	41	14.0	314	69	2.9	0.5	2.30	0.07	378	300	258	7.7
103	Ozaukee	Private	T9N, R21E, Section 30	143	662	6/10/74	0.02	0.09	130.0	46	93.0	433	44	170.0	0.2	16.00	0.03	812	510	355	7.2

Table 64 (continued)

USGS Well No.	County	Owner	Location	Depth of Well (feet)	Elevation of Bottom (feet-msl)	Date of Collection	Groundwater Quality Parameters[a] Iron[b] (Fe)	Manganese[b] (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate[b] (SO_4)	Chloride[b] (Cl)	Fluoride[b] (F)	Nitrate[b] (NO_3)	Nitrite (NO_2)	Dissolved Solids	Hardness as $CACO_3$	Alkalinity as $CACO_3$	pH (field)
105	Ozaukee	Private	T9N, R21E, Section 7	62	798	6/11/74	0.75	0.27	49.0	41	12.0	344	46	1.8	0.5	0.09	0.03	362	290	282	7.7
106	Ozaukee	Radke Homes	T9N, R21E, Section 20	186	599	6/11/74	0.01	0.27	81.0	39	4.9	358	52	8.1	0.2	4.00	0.16	401	360	294	7.5
107	Ozaukee	Gee-Jay Contractors	T9N, R21E, Section 22	340	322	6/12/74	0.00	0.09	89.0	30	13.0	266	170	2.9	0.7	0.31	0.00	537	350	218	7.7
113	Ozaukee	Private	T9N, R21E, Section 17	250	565	6/12/74	0.00	0.00	91.0	36	6.9	387	40	10.0	0.2	26.00	0.03	423	380	317	7.3
116	Ozaukee	Ponmeerow Builders	T9N, R21E, Section 8	158	662	6/12/74	0.35	33.00	170.0	53	17.0	255	430	5.7	0.6	0.58	0.00	934	640	209	7.2
287	Ozaukee	Private	T9N, R21E, Section 21	229	516	6/11/74	2.80	0.82	74.0	33	8.9	321	57	16.0	0.6	0.13	0.00	422	320	263	7.6
354	Ozaukee	Milwaukee Catholic Cemetery	T9N, R21E, Section 29	570	170	6/10/74	0.01	0.09	130.0	38	4.8	337	200	4.6	0.4	0.22	0.00	645	480	276	7.3
262	Milwaukee	Private	T8N, R21E Section 16	229	518	6/6/74	1.70	0.33	76.0	33	11.0	328	86	4.5	0.7	0.04	0.00	411	330	269	7.5
269	Milwaukee	Private	T7N, R21E Section 18	122	643	6/6/74	0.65	0.17	67.0	65	34.0	350	120	75.0	0.9	0.18	0.03	626	440	287	7.5
312	Milwaukee	Milwaukee Civil Defense	T7N, R21E, Section 9	295	462	6/13/74	0.02	0.14	25.0	11	52.0	140	97	3.9	1.5	1.20	0.03	284	110	115	7.9
439	Milwaukee	Private	T8N, R21E, Section 18	130	650	6/7/74	0.19	2.20	70.0	42	20.0	325	52	44.0	0.6	13.0	0.03	462	350	267	7.5
519	Milwaukee	Private	T8N, R21E, Section 19	204	594	5/31/74	0.66	0.14	74.0	64	27.0	343	100	86.0	0.6	1.10	0.00	636	450	281	7.4
520	Milwaukee	Private	T8N, R21E, Section 19	160	594	5/30/74	0.28	0.14	190.0	50	24.0	189	540	12.0	1.0	0.04	0.00	1,020	680	155	7.2
521	Milwaukee	Wisconsin Federal Savings and Loan	T8N, R21E, Section 9	156	589	6/6/74	2.20	0.33	75.0	29	15.0	314	76	2.8	0.5	0.09	0.03	398	310	258	7.4
531	Milwaukee	Flame Gas Corporation	T7N, R21E, Section 33	248	477	5/30/74	0.56	0.14	84.0	59	9.5	408	120	7.5	0.9	0.00	0.03	596	450	335	7.5
536	Milwaukee	Private	T8N, R21E, Section 7	361	429	6/7/74	7.60	1.00	290.0	60	4.0	249	770	3.1	1.0	0.00	0.03	1,360	970	204	7.2
539	Milwaukee	Wisconsin Electric	T7N, R22E, Section 32	565	25	6/6/74	0.78	0.50	110.0	51	32.0	480	56	74.0	1.1	1.80	0.03	622	480	394	7.6
130	Milwaukee	Greenfield (Southgate Manor) Townview Coop	T6N, R21E, Section 8	500	288	10/29/54	--	--	35.0	33	28.0	241	88	1.0	0.9	1.20	--	329	224	--	8.2
130	Milwaukee	Greenfield (Southgate Manor) Townview Coop	T6N, R21E, Section 8	500	288	2/11/47	--	--	29.0	28	33.0	235	66	2.0	0.9	0.80	--	299	188	--	7.6
139	Milwaukee	Little Mansions	T7N, R21E, Section 32	202	543	3/27/57	0.90	--	75.0	53	--	298	170	9.0	0.7	--	--	598	428	--	7.6
290	Milwaukee	Donner Packing Company	T7N, R22E, Section 31	464	--	1/17/52	0.90	--	100.0	53	32.0	386	130	46.0	1.1	0.60	--	592	470	--	8.4
327	Milwaukee	Barrettwoods	T7N, R21E, Section 5	377	361	4/3/57	0.05	--	56.0	34	--	264	80	5.0	0.6	--	--	378	278	--	7.8
360	Milwaukee	Suburban Homes	T7N, R21E, Section 5	305	430	4/9/57	0.10	--	65.0	32	32.0	215	150	5.5	0.7	--	--	502	312	--	7.7
385	Milwaukee	Hampton Heights Subdivision	T8N, R21E, Section 31	360	390	4/10/57	0.50	--	72.0	31	26.0	242	140	4.5	0.6	--	--	478	324	--	7.6
403	Milwaukee	Zurich Subdivision	T7N, R21E, Section 19	306	419	3/28/57	0.20	--	67.0	47	--	439	84	5.0	0.8	--	--	494	390	--	7.8
337	Milwaukee	Robert William Park	T8N, R21E, Section 32	305	410	8/23/66	0.12	--	180.0	40	19.0	248	440	4.6	0.3	1.80	--	918	617	--	7.5
337	Milwaukee	Robert William Park	T8N, R21E, Section 32	305	410	4/17/57	0.10	--	170.0	40	--	251	330	4.0	0.6	--	--	966	599	--	7.4
559	Milwaukee	Colony Home	T7N, R21E, Section 32	354	408	8/18/66	0.46	--	66.0	30	14.0	259	100	9.0	0.7	2.70	--	358	289	--	7.8
559	Milwaukee	Colony Home	T7N, R21E, Section 32	354	408	4/2/57	0.30	--	58.0	30	--	254	63	7.0	0.6	--	--	332	266	--	7.8
123	Milwaukee	Van Dyke Water Coop	T6N, R21E, Section 10	405	375	8/17/66	0.13	0.03	24.0	13	46.0	163	85	4.2	1.2	2.20	--	258	113	--	7.9
123	Milwaukee	Van Dyke Water Coop	T6N, R21E, Section 10	405	375	4/3/57	0.05	--	30.0	16	50.0	181	63	3.0	1.0	--	--	278	139	--	8.2
123	Milwaukee	Van Dyke Water Coop	T6N, R21E, Section 10	405	375	7/26/45	0.00	--	15.0	7	48.0	127	74	7.5	1.3	--	--	218	74	--	7.9
127	Waukesha	Private	T7N, R20E, Section 26	421	450	6/10/74	0.01	0.14	68.0	58	14.0	411	82	6.3	0.7	0.62	0.03	446	410	337	7.5

Table 64 (continued)

USGS Well No.	County	Owner	Location	Depth of Well (feet)	Elevation of Bottom (feet-msl)	Date of Collection	Groundwater Quality Parameters[a]: Iron (Fe)	Manganese[b] (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate[b] (SO_4)	Chloride[b] (C)	Fluoride[b] (F)	Nitrate[b] (NO_3)	Nitrite (NO_2)	Dissolved Solids	Hardness as $CACO_3$	Alkalinity as $CACO_3$	pH (field)
136	Waukesha	Lyndale Subdivision Coop	T7N, R20E, Section 13	490	310	6/10/74	0.66	0.14	100.0	47	15.0	291	210	10.0	0.7	0.15	0.03	577	440	239	7.4
147	Waukesha	Private	T7N, R20E, Section 25	200	544	6/10/74	0.71	0.57	120.0	73	75.0	459	85	230.0	0.6	0.62	0.03	901	600	376	7.2
155	Waukesha	Pilgrim Park Junior High	T7N, R20E, Section 23	380	448	6/12/74	0.00	0.09	69.0	33	11.0	345	50	1.6	0.7	0.27	0.03	344	310	283	7.5
167	Waukesha	Best Block Company	T8N, R20E, Section 25	225	573	6/12/74	0.03	0.09	86.0	48	8.6	390	70	23.0	0.4	0.27	0.00	446	410	320	7.4
187	Waukesha	Mt. Zion Cemetery	T7N, R20E, Section 14	300	462	6/10/74	0.00	0.86	78.0	34	23.0	254	150	19.0	0.7	0.22	0.03	462	330	208	7.5
246	Waukesha	North Hill Country Club	T8N, R20E, Section 13	420	375	6/12/74	0.00	0.09	79.0	35	40.0	220	230	12.0	0.9	0.13	0.00	553	340	180	7.7
721	Waukesha	Elm Brook School District 21	T7N, R20E, Section 24	300	448	6/10/74	0.13	0.14	68.0	42	23.0	262	140	22.0	0.8	0.00	0.03	464	340	215	7.5
722	Waukesha	Employers Mutual	T7N, R20E, Section 27	360	485	6/11/74	2.30	0.27	340.0	54	8.8	274	790	1.7	0.5	0.00	0.03	1,460	1,100	225	7.3
234	Waukesha	Wirth Park	T7N, R20E, Section 15	350	480	6/11/74	0.00	0.00	46.0	37	17.0	308	42	2.2	0.9	1.40	0.03	319	270	253	7.8
321	Waukesha	Private	T8N, R20E, Section 9	116	850	6/12/74	0.00	0.27	79.0	45	12.0	378	50	27.0	0.2	7.50	0.03	492	380	310	7.3
129	Waukesha	Riverview Manor	T8N, R20E, Section 35	250	544	8/17/66	0.91	0.08	83.0	45	9.5	375	83	10.0	0.5	2.20	--	462	396	--	7.8
129	Waukesha	Riverview Manor	T8N, R20E, Section 35	250	544	3/22/63	0.48	0.04	76.0	42	--	367	62	7.5	0.2	0.40	--	428	364	--	7.4
156	Waukesha	Silver Springs Subdivision	T8N, R20E, Section 35	305	490	8/17/66	1.80	0.03	68.0	48	15.0	370	93	12.0	0.6	2.20	--	456	372	--	7.7
156	Waukesha	Silver Springs Subdivision	T8N, R20E, Section 35	305	490	3/22/63	0.56	0.04	65.0	48	--	365	76	7.5	0.4	0.40	--	426	360	--	7.5
229	Waukesha	Milwaukee Electric Tool	T7N, R20E, Section 1	385	370	11/10/72	4.40	--	120.0	59	47.0	334	160	140.0	0.3	0.40	--	720	540	--	7.9
240	Waukesha	Mission Heights Subdivision	T7N, R20E, Section 14	360	434	8/30/66	1.10	--	74.0	44	12.0	343	88	12.0	0.8	2.10	--	462	370	--	7.6
240	Waukesha	Mission Heights Subdivision	T7N, R20E, Section 14	360	434	7/20/65	0.54	0.03	--	--	--	--	--	--	--	--	--	--	328	--	8.3
768	Waukesha	Westchester Water Company	T7N, R20E, Section 34	318	610	8/10/66	0.08	0.03	73.0	36	4.4	381	30	2.6	0.4	1.80	--	368	334	--	7.7
768	Waukesha	Westchester Water Company	T7N, R20E, Section 34	318	610	6/5/63	0.80	0.04	75.0	39	--	381	32	4.0	0.2	0.50	--	364	348	--	7.3
						Minimum	0.00	0.00	3.6	7	3.0	127	1	1.0	0.1	0.00	0.00	216	74	115	7.2
						Mean	0.56	0.83	88.1	42	18.4	326	126	21.0	0.6	3.76	0.07	518	395	280	7.6
						Maximum	7.60	33.00	340.0	87	93.0	480	790	230.0	1.5	44.00	0.82	1,460	1,100	394	8.4

[a]*Analyses in mg/l except pH, which is in standard units.*

[b]*Parameters for which Wisconsin Department of Natural Resources drinking water standards are available.*

Source: U. S. Geological Survey.

limit and 81 percent of the 64 manganese analyses were in excess of the 0.05 mg/l limit. Iron concentrations varied from no detectable amounts to 7.60 (mg/l) and averaged 0.56 mg/l, whereas manganese levels ranged from no detectable amount to 33.00 mg/l with a mean of 0.83 mg/l. Dolomite aquifer wells containing iron and manganese do not appear to be concentrated in any particular portion of the watershed.

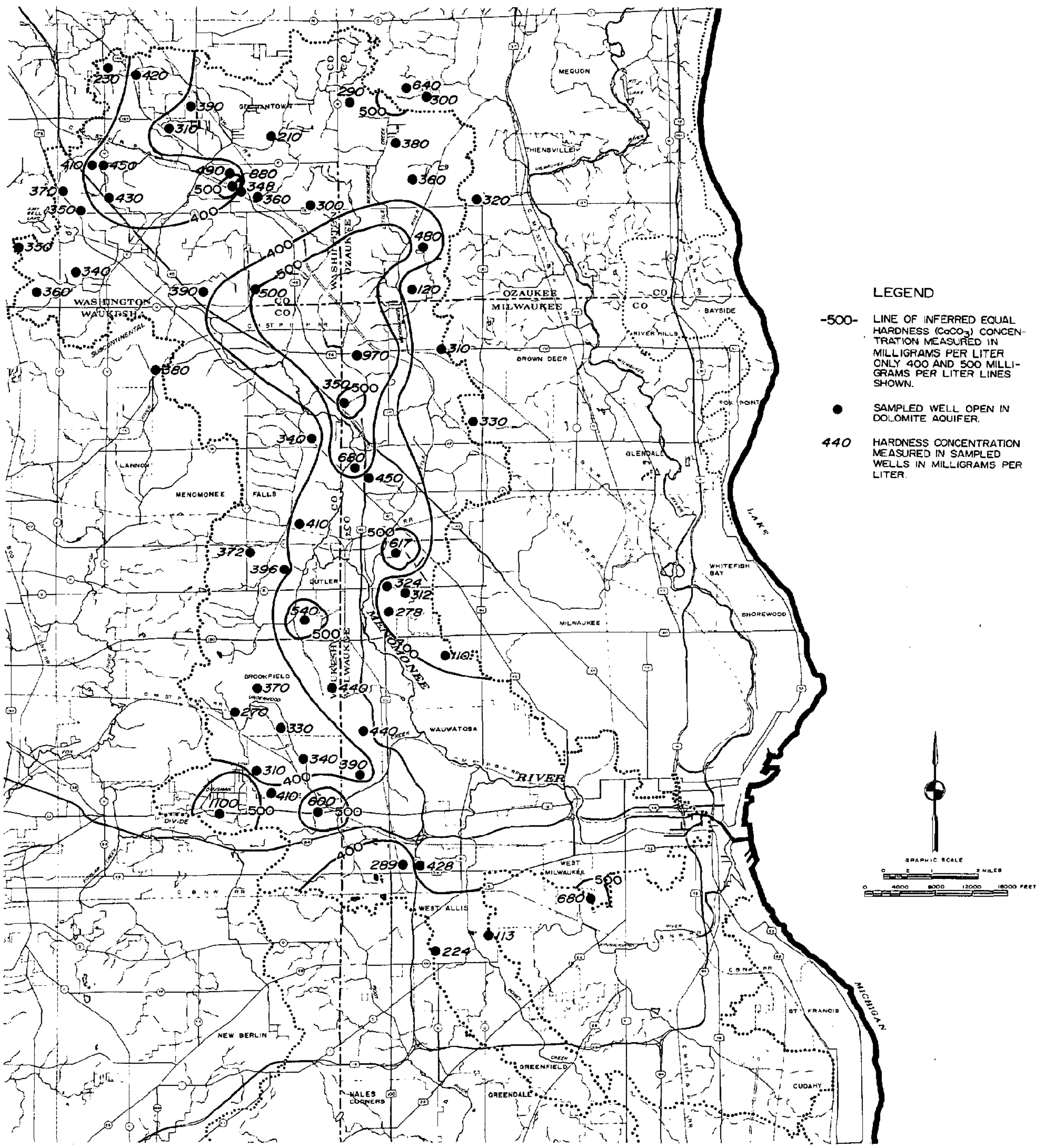
In summary then, of the six parameters for which drinking water standards have been established and data are available—iron, manganese, sulfate, chloride, fluoride, and nitrate—water from the dolomite aquifer contains high iron and manganese concentrations and acceptable levels of the other four constituents.

Map 74 illustrates the spatial distribution of hardness in the watershed expressed as calcium carbonate. Hardness values ranging from 74 to 1,100 mg/l have been recorded for the dolomite aquifer in or near the watershed with a mean value of 395 mg/l. As indicated by the study, there are no large areas within the watershed where the dolomite aquifer may be characterized as having very high or very low levels of hardness.

Although water from the dolomite aquifer is considered "hard" for domestic use, there are no public water utilities serving the communities within the Menomonee River watershed which treat the raw water to remove part of the hardness. Many homeowners, served by both private and public water supplies, operate their own

Map 74

APPROXIMATE DISTRIBUTION OF HARDNESS IN THE DOLOMITE AQUIFER IN THE MENOMONEE RIVER WATERSHED



Hardness values ranging from 74 to 1,100 mg/l have been recorded for water drawn from the dolomite aquifer in or near the watershed with a mean value of 395 mg/l. The Village of Germantown, Village of Menomonee Falls, and City of Brookfield water utilities all draw some of their supply from the dolomite aquifer, although none of these public water utilities treats the raw water to reduce the hardness prior to distribution.

Source: U. S. Geological Survey.

water-softening units, however. Comparison of hardness data set forth in Table 64 and displayed on Map 74 with the water quality standards listed in Table 60 indicates that water from the dolomite aquifer is also considered hard for some industrial-commercial uses. As a result, and as noted later in this chapter, some self-supplied industrial-commercial users employ water softening processes.

The distribution of dissolved solids concentrations in the dolomite aquifer is shown on Map 75. Dissolved solids values ranging from 216 to 1,460 mg/l have been recorded for the aquifer, with a mean value of 518 mg/l. As indicated by the map, there are no large areas in the watershed where the dolomite aquifer may be characterized as having very high or very low values of dissolved solids. Based on the dissolved solids data set forth in Table 64 and shown on Map 75 and the water use standards set forth in Table 60, dolomite aquifer wells within the watershed may be expected to yield water containing dissolved solids concentrations acceptable for most industrial-commercial water uses.

The Sandstone Aquifer: Table 65 summarizes the results of the analyses of 60 water quality samples from the 22 sample wells open to the sandstone aquifer collected during the period February 11, 1947, to November 9, 1972. The percentages of the sandstone aquifer samples exceeding the recommended drinking water standards are shown in Table 63.

The chloride and fluoride standards were not exceeded in any of the available samples. Similarly the nitrate standard was not exceeded in any of the samples. Unlike the dolomite aquifer which generally met the sulfate standard of 250 mg/l, excessive sulfate concentrations were reported for 45 percent of 53 samples. Sulfate levels ranged from 40 to 1,000 mg/l and averaged 262 mg/l. Very high iron and manganese levels also were found in water from the sandstone aquifer in that 79 percent of the 53 samples contained iron plus manganese concentrations in excess of 0.35 mg/l.[40] Iron plus manganese concentrations varied from no detectable amount to 2.80 mg/l, with an average level of 0.68 mg/l. An examination of the location of the wells containing iron and manganese did not reveal any tendency for such wells to be located in any particular portion of the watershed.

In summary, of the six parameters for which drinking water standards have been established and data are available—iron, manganese, sulfate, chloride, fluoride, and nitrate—water in the sandstone aquifer contains very high levels of sulfate, iron, and manganese while exhibiting acceptable levels of the remaining three constituents.

Hardness analyses conducted on 60 samples of water drawn from the sandstone aquifer yielded concentrations ranging from 285 to 1,280 mg/l with an average level of 468 mg/l. Therefore, the water is considered "hard" for general domestic use and for some industrial-commercial uses.

The Dolomite and Sandstone Aquifers: Table 66 summarizes the results of analyses of 41 water quality samples collected from 23 sample wells open to both the dolomite and sandstone aquifers during the period May 1, 1946, to March 30, 1972. The proportion of samples exceeding recommended drinking water standards is presented in Table 63.

The chloride standard was not exceeded in any of the 40 available samples and similarly, there were no instances of excessive fluoride in 39 samples, or excessive nitrate in 24 samples. Sulfate concentrations in excess of the 250 mg/l standard were reported for 25 percent of the 36 samples with sulfate concentrations ranging from 41 to 570 mg/l and averaging 196 mg/l. Excessive levels of iron and manganese are likely in wells tapping the two aquifers in that 47 percent of 38 samples contained iron plus manganese in excess of 0.35 mg/l. Iron plus manganese concentrations varied from no detectable quantity to 3.00 mg/l with an average of 0.53 mg/l. An examination of the spatial distribution of the wells containing iron and manganese indicates that this problem is distributed rather uniformly over the watershed, that is, it is not concentrated in any particular portions of the basin.

In summary, then, of the six parameters for which drinking water standards have been established and for which data are available—iron, manganese, sulfate, chloride, fluoride, and nitrate—water from wells open to both the dolomite and sandstone aquifers generally may be expected to contain moderate sulfate concentrations and high iron and manganese levels. The other three constituents are generally present in concentrations that meet the drinking water quality standards.

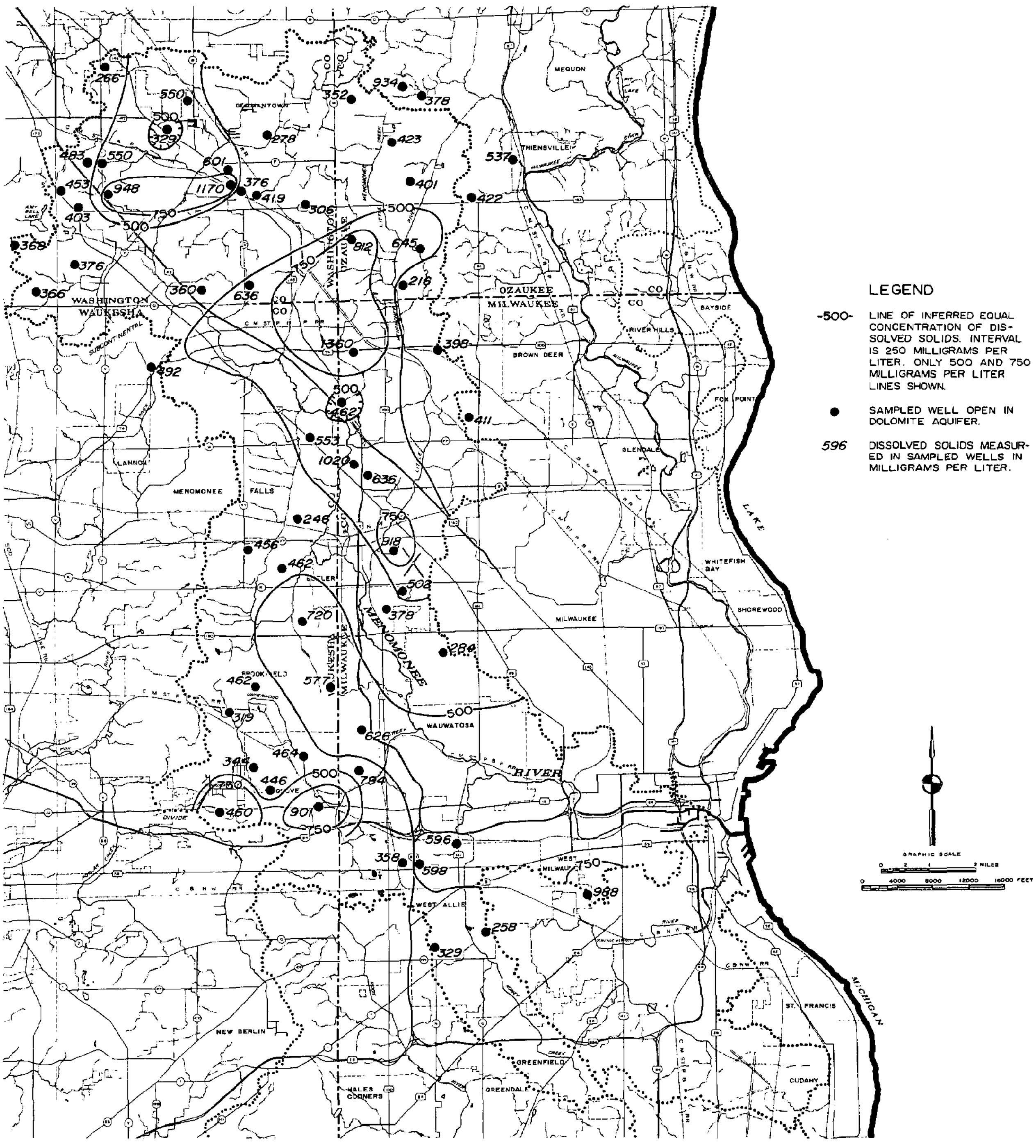
Hardness analyses conducted on 41 water samples taken from wells open to both the dolomite and sandstone aquifers yield values ranging from 105 to 770 mg/l with a mean of 395 mg/l. As was true with the other aquifers, this water would be considered "hard" for general domestic use and for some commercial-industrial uses.

Concluding Statement: Groundwater Quality by Aquifer: For drinking water use, the water from the sand and gravel aquifer appears to be of a high quality in that only the iron and manganese content may be expected to exceed the established standards. This observation must be tempered, however, by the realization that this aquifer is most readily susceptible to contamination as a result of man's activities. Water from the dolomite aquifer may be expected to contain excessive concentrations of iron and manganese, whereas water from the sandstone aquifer and from wells tapping both the sandstone and dolomite

[40]*Combined iron and manganese analyses were performed on the samples from the sandstone aquifer rather than separate analyses of iron and of manganese. Therefore, the sum of the iron and manganese content of each sample was compared, for purposes of this table, to the sum of the iron and manganese standards—0.35 mg/l. If the iron plus manganese concentration exceeds 0.35 mg/l, it follows that the sample contains excess iron or excess manganese or an excess of both of these metals.*

Map 75

APPROXIMATE DISTRIBUTION OF DISSOLVED SOLIDS IN THE DOLOMITE AQUIFER IN THE MENOMONEE RIVER WATERSHED



Dissolved solids values ranging from 216 to 1,460 mg/l have been recorded for the aquifer, with a mean value of 518 mg/l. As indicated by the map, there are no large areas in the watershed where the dolomite aquifer may be characterized as having very high or very low values of dissolved solids.

Source: U. S. Geological Survey.

Table 65

CHEMICAL ANALYSES OF GROUNDWATER FROM THE SANDSTONE AQUIFER IN THE MENOMONEE RIVER WATERSHED

							Groundwater Quality Parameters[a]																
USGS Well No.	County	Owner	Location	Depth of Well (feet)	Elevation of Bottom (feet-msl)	Date Collection	Iron[b,c] (Fe)	Manganese[b,c] (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate[c] (SO_4)	Chloride[c] (Cl)	Fluoride[c] (F)	Nitrate[c] (NO_3)	Nitrite (NO_2)	Dissolved Solids	Hardness as $CACO_3$	Alkalinity as $CACO_3$	pH (field)
30	Washington	Pilgrim Heights Subdivision	T9N, R20E, Section 34	1,302	- 402	11/9/72	0.06	--	100	28	7.6	320	110	3.9	0.1	0.0	--	458	360	--	8.1
						7/17/69	0.31	--	118	18	7.2	314	116	3.0	0.5	0.2	--	468	369	--	8.0
						4/25/68	0.37	--	102	28	7.0	328	105	5.0	0.3	0.1	--	459	370	--	7.7
						5/24/67	0.59	--	111	23	7.1	326	109	6.0	0.3	0.2	--	464	372	--	7.7
						7/29/66	0.62	--	107	26	5.1	320	110	0.9	0.3	1.8	--	450	375	--	7.8
						4/12/66	0.52	--	--	--	--	324	115	5.5	0.2	0.1	--	469	388	--	7.6
						3/29/65	0.37	--	102	30	8.4	314	116	7.0	0.0	0.0	--	464	378	--	7.6
						8/24/64	--	--	104	25	7.2	315	112	5.5	--	0.0	--	--	364	--	7.3
						11/29/63	0.91	--	--	--	9.8	324	118	6.0	--	--	--	473	372	--	7.1
						5/3/63	--	--	--	--	8.8	320	118	6.0	--	--	--	468	368	--	7.4
243	Waukesha	Village of Butler	T8N, R20E, Section 36	1,697	- 937	8/14/67	0.47	--	117	21	8.5	171	245	8.0	0.6	--	--	546	380	--	7.4
						11/18/65	0.39	--	111	22	--	180	180	10.0	0.3	0.3	--	--	372	--	7.3
758	Waukesha	Village of Menomonee Falls	T8N, R20E, Section 9	1,379	- 479	6/1/72	0.37	--	120	21	11.0	266	160	20.0	0.4	0.0	--	512	390	--	7.9
						10/26/67	1.04	--	88	39	10.0	256	154	15.0	0.6	0.7	--	586	380	--	7.7
148	Waukesha	Village of Menomonee Falls	T8N, R20E, Section 3	1,322	- 522	7/28/66	0.40	--	142	23	9.1	285	220	7.0	0.4	1.8	--	602	454	--	7.7
						1/11/66	0.26	--	138	25	--	--	--	11.0	0.4	--	--	--	448	--	--
						3/30/65	0.32	--	--	--	--	293	--	--	--	--	--	--	420	--	7.3
						9/14/64	0.12	--	--	--	--	--	--	11.0	0.3	--	--	--	430	--	--
						6/6/63	0.38	--	139	26	--	282	250	10.0	0.2	0.1	--	622	455	--	7.4
321	Milwaukee	Kearney and Trecker	T7N, R21E, Section 31	1,750	- 1,005	6/14/61	0.93	--	--	--	--	224	298	12.0	0.3	0.4	--	--	462	--	7.1
						2/1/57	0.30	--	224	35	24.0	246	437	15.0	--	0.0	--	891	642	--	7.6
409	Milwaukee	Brookview Park	T7N, R21E Section 30	1,305	- 585	4/17/57	0.20	--	88	22	--	204	140	11.0	0.4	--	--	462	320	--	7.7
14	Milwaukee	City of Wauwatosa	T7N, R21E, Section 27	1,704	- 1,049	6/15/62	0.56	--	152	26	--	215	352	13.0	--	--	--	728	486	--	7.9
						6/13/61	0.72	--	--	--	--	216	347	12.0	0.3	0.4	--	--	522	--	6.9
						5/21/52	0.00	--	130	28	14.0	209	279	12.0	0.4	0.2	--	617	440	--	7.6
						6/17/47	1.00	--	169	26	--	224	380	13.0	0.5	--	--	732	460	--	7.3
19	Milwaukee	Washington Park	T7N, R21E, Section 23	1,837	- 1,112	2/13/47	--	--	158	29	30.0	235	361	13.0	0.2	0.2	--	770	513	--	7.6
455	Milwaukee	Mayfair Shopping Center	T7N, R21E, Section 17	1,750	- 1,025	6/1/72	0.99	--	150	19	10.0	182	300	12.0	0.4	0.1	--	630	450	--	7.9
						8/25/69	0.62	--	141	29	12.0	194	304	9.0	0.4	0.0	--	654	471	--	7.6
						4/25/68	0.85	--	143	26	9.9	188	302	8.0	0.4	0.2	--	642	464	--	7.7
						5/24/67	0.54	--	147	24	10.0	188	292	10.0	0.4	0.2	--	640	466	--	7.7
						4/12/66	0.60	--	--	--	--	186	296	9.0	0.4	0.1	--	628	462	--	7.6
						3/29/65	0.61	--	136	30	12.0	180	298	9.5	0.1	0.1	--	628	463	--	7.8
						8/26/64	0.74	--	129	29	11.0	185	298	62.0	--	0.0	--	--	485	--	7.2
						11/29/63	0.76	--	--	--	12.0	184	284	8.0	--	--	--	607	432	--	7.1
						5/3/63	0.00	--	--	--	13.0	190	300	8.0	--	--	--	662	455	--	7.4
285	Milwaukee	City of Wauwatosa	T7N, R21E, Section 15	1,750	- 970	6/13/61	1.73	--	--	--	--	214	413	12.0	0.3	0.3	--	--	580	--	7.0
						5/21/52	0.73	--	136	28	12.0	200	305	13.0	0.3	0.2	--	651	455	--	7.4
1	Milwaukee	Harley Davidson	T7N, R21E, Section 6	1,726	- 991	5/2/50	0.10	--	74	37	--	273	125	7.0	1.6	--	--	400	320	--	7.6
398	Milwaukee	Parkway Home-Site	T7N, R21E, Section 6	1,400	- 670	3/22/66	0.75	--	32	23	9.1	148	180	8.5	0.5	1.8	--	462	324	--	8.2
166	Waukesha	City of Brookfield	T7N, R20E, Section 36	1,029	- 219	8/9/66	0.75	--	93	26	20.0	249	168	11.0	0.5	2.2	--	504	340	--	7.8
146	Waukesha	Notre Dame Convent	T7N, R20E, Section 25	1,215	- 455	3/26/58	--	--	--	--	--	449	--	--	--	--	--	--	512	--	7.6
						3/26/58	--	--	--	--	--	432	--	--	--	--	--	--	506	--	7.4
701	Waukesha	Subdividers Inc.	T7N, R20E, Section 21	1,800	- 865	8/29/66	1.00	--	71	36	6.1	359	40	5.0	0.4	2.1	--	394	344	--	7.4
356	Waukesha	Elmbrook Memorial Hospital	T7N, R20E, Section 20	1,570	- 720	6/6/72	0.46	--	67	35	19.0	270	110	16.0	0.6	0.8	--	418	310	--	7.5
						4/20/66	0.38	--	--	--	--	281	--	--	--	--	--	--	306	--	--
178	Waukesha	Imperial Estates	T7N, R20E, Section 4	1,742	- 857	8/9/66	0.46	--	30	20	16.0	211	130	12.0	0.5	1.8	--	410	285	--	8.2

Table 65 (continued)

							Groundwater Quality Parameters[a]														
USGS Well No.	County	Owner	Location	Depth of Well (feet)	Elevation of Bottom (feet-msl)	Date Collection	Iron[b,c] (Fe)	Manganese[b,c] (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate[c] (SO_4)	Chloride[c] (Cl)	Fluoride[c] (F)	Nitrate[c] (NO_3)	Nitrite (NO_2)	Dissolved Solids	Hardness as $CACO_3$	Alkalinity as $CACO_3$	pH (field)
91	Milwaukee	Village of Greendale	T6N, R21E, Section 34	1,855	- 1,090	2/20/64	--	--	276	20	--	246	520	12.0	0.5	0.2	--	1,090	774	--	7.2
						6/15/61	1.46	--	--	--	--	226	613	12.0	0.3	0.4	--	--	784	--	7.2
						4/7/58	1.70	--	408	30	--	254	1,000	14.0	0.7	--	--	1,540	1,100	--	--
						6/27/55	2.80	--	--	--	--	283	--	--	--	--	--	--	1,280	--	7.4
						4/23/47	1.60	--	431	24	--	250	1,000	18.0	0.8	--	--	1,730	990	--	7.3
92	Milwaukee	Village of Greendale	T6N, R21E, Section 34	1,865	- 1,135	2/20/64	1.40	--	228	24	--	273	420	10.0	0.5	0.1	--	932	668	--	7.2
						6/24/55	0.70	--	131	24	--	281	170	12.0	0.5	--	--	612	430	--	7.6
						4/23/47	0.20	--	134	21	--	283	230	12.0	0.4	--	--	610	360	--	7.0
						2/11/47	--	--	118	25	32.0	280	223	11.0	0.3	0.5	--	597	398	--	7.5
435	Milwaukee	Regal Manor Subdivision	T6N, R21E, Section 22	1,316	- 526	8/16/66	1.23	--	88	28	17.0	266	145	11.0	0.5	2.1	--	468	338	--	7.5
350	Waukesha	City of New Berlin	T6N, R20E, Section 3	1,800	- 940	6/6/72	0.64	--	120	28	16.0	302	160	16.0	0.5	0.1	--	524	410	--	7.8
						8/18/66	0.62	--	119	25	17.0	305	165	14.0	1.0	1.1	--	542	400	--	7.8
233	Waukesha	Forest View Heights	T6N, R20E, Section 1	1,500	- 665	8/18/64	0.57	--	96	38	18.0	295	143	14.0	0.5	2.2	--	484	398	--	7.7
						Minimum	0.00	--	30	18	5.1	148	40	0.9	0.0	0.0	--	394	285	--	6.9
						Mean	0.68	--	137	27	12.8	259	262	11.2	0.4	0.6	--	624	468	--	7.5
						Maximum	2.80	--	408	39	32.0	449	1,000	62.0	1.6	2.2	--	1,730	1,280	--	8.2

[a]*Analyses in Mg/l except pH, which is in standard units.*

[b]*Values for Iron (Fe) and Manganese (Mn) concentrations are combined and recorded in the Iron column.*

[c]*Parameters for which Wisconsin Department of Natural Resources drinking water standards are available.*

Source: U. S. Geological Survey and SEWRPC.

aquifers may be expected to contain excessive concentrations of iron, manganese, and sulfate. Water from all three aquifers is considered "hard" for general domestic use and for some industrial-commercial uses. Within any aquifer, there is no apparent tendency for substandard water to be located in any particular portion of the watershed.

Present and Potential Groundwater Pollution

Pollution Sources: Pollution of groundwater by wastes resulting from varied human activity is an existing and potential problem within the watershed. Seepage of domestic, municipal, industrial, and agricultural wastes into the shallow groundwater aquifer may occur from many potential sources. These include, but are not restricted to, private onsite sewage disposal systems (septic tanks), refuse dumps, barnyards, cesspools and sewage lagoons, privies and dry wells, industrial spillages, leakage from community sewage systems and seepage from agricultural lands, and influent (losing) streams, all of which are more apt to adversely affect the shallow aquifer than the deep aquifer. The potential for pollution of the shallow aquifer may be increased during and immediately after periods of wet weather when discharges from combined sewer outfalls and from sanitary sewer flow relief devices such as crossovers, bypasses, relief pumping stations, and portable pumping stations may reach influent stream segments.

Problems involving pollution of groundwater generally are much more difficult to solve than problems involving pollution of surface water because the hidden paths of groundwater contaminants cannot be easily traced. Other potential sources of groundwater pollution of both the shallow and deep aquifers have not been, and cannot as yet be, fully evaluated. These include the long-term effects of nitrates, detergents,[41] insecticides, herbicides, and fertilizers on groundwater quality.

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[41] *Since December 31, 1965, the sale of non-biodegradable (hard) detergents containing Alkyl benzene sulfonate has been prohibited in Wisconsin by Section 144.14 of the Wisconsin Statutes. In accordance with this legislation, the detergent industry has developed biologically degradable (soft) detergents and placed these on the market so that today all detergents presently being sold in Wisconsin are of the "soft" type. It is of interest to note that while elimination of the foaming characteristic of detergents has improved the aesthetic condition of surface waters, it has also eliminated a useful indicator of potential pollution in private groundwater supplies where such supplies are used in conjunction with onsite waste disposal systems. Prior to the development of non-biodegradable detergents, the presence of persistent foam on the surface of water drawn from a private groundwater supply indicated a likely hydraulic connection to a nearby onsite waste disposal system and, therefore, provided a warning of possible pollution. The advent of biodegradable detergents has eliminated this visual warning of potential pollution of private water supplies.*

Table 66

CHEMICAL ANALYSES OF GROUNDWATER FROM THE DOLOMITE AND SANDSTONE AQUIFERS IN THE MENOMONEE RIVER WATERSHED

USGS Well No.	County	Owner	Location	Depth of Well (feet)	Elevation of Bottom (feet/msl)	Date of Collection	Groundwater Quality Parameters[a]														
							Iron[b,c] (Fe)	Manganese[b,c] (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_2)	Sulfate[c] (SO_4)	Chloride[c] (Cl)	Fluoride[c] (F)	Nitrate[c] (NO_3)	Nitrite (NO_2)	Dissolved Solids	Hardness as $CACO_3$	Alkalinity as $CACO_3$	pH (field)
22	Ozaukee	Village Heights Subdivision	T9N, R21E, Section 22	559	146	7/29/66	0.50	--	72	29	18.0	233	130	3.3	0.7	1.8	--	--	300	--	--
422	Milwaukee	Village of Brown Deer	T8N, R21E, Section 10	300	405	10/26/61	0.83	--	92	37	--	325	134	3.0	0.8	--	--	--	382	--	7.5
224	Waukesha	Village of Menomonee Falls	T8N, R20E, Section 11	62	713	9/28/65	1.40	--	42	--	--	--	--	42.0	0.6	--	--	--	375	--	--
3	Waukesha	Village of Menomonee Falls	T8N, R20E, Section 10	1,140	- 355	12/13/46	0.00	--	92	48	--	424	70	24.0	0.4	--	--	512	435	--	7.1
						5/1/46	0.00	--	96	46	--	429	90	25.0	0.2	--	--	530	450	--	7.1
4	Waukesha	Village of Menomonee Falls	T8N, R20E, Section 3	1,408	- 538	7/28/66	0.14	--	117	30	8.6	305	155	7.5	0.4	1.8	--	536	418	--	7.7
						1/11/66	0.04	--	111	31	--	--	--	12.0	0.4	--	--	--	415	--	--
						9/14/65	0.12	--	--	--	--	--	--	13.0	0.3	--	--	--	458	--	--
						3/30/65	0.18	--	--	--	--	393	--	--	--	--	--	--	468	--	7.1
						6/6/63	0.06	--	106	47	--	398	112	10.0	0.2	6.2	--	546	462	--	7.2
						12/13/46	0.00	--	114	44	--	373	165	14.0	0.4	--	--	564	360	--	7.2
						5/1/46	0.00	--	108	41	--	400	170	13.0	0.4	--	--	566	470	--	7.3
46	Milwaukee	Boston Store	T7N, R22E, Section 29	1,400	- 805	5/15/47	--	--	136	43	26.0	389	196	36.0	0.9	0.2	--	725	516	--	7.3
22	Milwaukee	Allis Chalmers	T7N, R21E, Section 34	1,690	970	3/30/72	0.86	--	220	32	12.0	248	460	11.0	0.5	0.3	--	940	680	--	7.3
						6/15/62	1.40	--	44	50	--	345	82	9.5	--	--	--	418	316	--	7.6
						6/19/61	1.14	--	--	--	--	246	570	10.0	0.6	0.4	--	--	770	--	6.8
16	Milwaukee	City of Wauwatosa	T7N, R21E, Section 28	1,714	- 1,017	5/21/52	0.25	--	128	33	12.0	248	267	10.0	0.5	0.2	--	637	455	--	7.5
						6/17/47	0.50	--	76	48	--	373	90	10.0	0.7	--	--	466	410	--	7.5
149	Milwaukee	City of Wauwatosa	T7N, R21E, Section 22	1,692	- 932	6/6/52	1.80	--	161	31	14.0	206	367	10.0	0.4	0.1	--	742	530	--	7.5
						6/17/47	3.00	--	86	36	--	261	190	20.0	0.5	--	--	508	390	--	7.4
17	Milwaukee	City of Wauwatosa	T7N, R21E, Section 22	1,660	- 900	6/6/52	0.59	--	150	29	12.0	208	334	10.0	0.3	0.0	--	699	495	--	7.4
						6/17/47	0.20	--	116	25	--	215	225	12.0	0.5	--	--	562	365	--	7.4
18	Milwaukee	City of Wauwatosa	T7N, R21E Section 20	1,675	- 900	5/21/52	0.46	--	116	27	12.0	188	259	9.0	0.3	0.2	--	570	400	--	7.5
						6/17/47	1.40	--	120	23	--	188	235	13.0	0.4	--	--	564	360	--	7.5
15	Milwaukee	City of Wauwatosa	T7N, R21E, Section 15	1,804	- 1,059	6/13/61	0.30	--	--	--	--	222	181	6.0	0.9	0.6	--	--	325	--	7.7
						5/21/52	0.31	--	172	27	13.0	207	383	12.0	0.4	0.2	--	739	540	--	7.4
						1/1/52	0.38	--	34	25	23.0	230	41	2.4	1.4	0.8	--	248	186	--	7.9
						6/17/47	0 10	--	99	24	--	215	190	10.0	0.7	--	--	492	330	--	7.5
388	Milwaukee	Barrett Woods	T7N, R21E, Section 6	375	370	4/9/57	0.04	--	51	30	25.0	251	84	5.0	0.7	--	--	360	260	--	7.8
2	Waukesha	Marion Heights Subdivision	T7N, R20E, Section 24	1,708	- 938	11/29/67	0.10	--	72	27	27.0	210	134	9.0	1.0	0.5	--	428	290	--	7.3
						3/22/63	0.12	--	66	29	23.0	224	146	7.0	0.8	0.8	--	422	286	--	7.6
238	Waukesha	Dominic Heights Subdivision	T7N, R20E, Section 9	1,635	- 760	12/8/67	0.60	--	74	33	24.0	268	120	22.0	0.7	0.4	--	450	320	--	7.5
						10/27/65	--	--	--	--	--	254	--	24.0	0.4	--	--	--	336	--	8.1
237	Waukesha	Dominic Heights Subdivision	T7N, R20E, Section 9	359	516	8/9/66	0.48	--	54	24	4.0	265	55	2.3	0.7	1.8	--	304	237	--	8.0
210	Waukesha	Imperial Estate	T7N, R20E, Section 4	350	570	8/9/66	0.26	--	78	27	11.0	278	100	6.0	0.5	1.8	--	384	309	--	7.8
80	Milwaukee	Maynard Electric	T6N, R22E, Section 7	1,727	- 1,082	3/11/47	--	--	183	25	25.0	240	397	5.8	0.6	0.2	--	826	560	--	7.3
493	Milwaukee	Southgate Manor	T7N, R21E, Section 24	965	- 230	8/17/66	0.33	--	49	28	27.0	255	80	2.3	1.2	2.7	--	352	237	--	7.9
560	Milwaukee	Townview Water	T6N, R21E, Section 14	960	- 205	8/16/66	0.17	--	25	10	59.0	95	150	4.1	1.2	3.1	--	316	105	--	7.9
233	Milwaukee	Broson Manor	T6N, R21E, Section 9	1,076	- 271	8/18/66	0.35	--	59	20	38.0	233	130	4.6	0.8	0.5	--	368	229	--	7.8
34	Milwaukee	Bronson Manor	T6N, R21E, Section 9	1,060	- 255	8/18/66	1.03	--	68	51	27.0	337	170	5.5	0.7	0.5	--	524	382	--	7.6
326	Milwaukee	Kurth Malt Company	T6N, R21E, Section 1	1,755	- 1,100	6/16/61	0.75	--	--	--	--	256	390	11.0	0.3	0.2	--	--	576	--	6.9
						Minimum	0.00	--	25	10	4.0	95	41	2.3	0.2	0.0	--	248	105	--	6.8
						Mean	0.53	--	97	33	21.0	275	196	11.7	0.6	1.1	--	526	395	--	7.5
						Maximum	3.00	--	220	51	59.0	429	570	42.0	1.4	6.2	--	940	770	--	8.1

[a] Analyses in mg/l except pH, which is in standard units.

[b] Values for Iron (Fe) and Manganese (Mn) concentrations are combined and recorded in the Iron column.

[c] Parameters for which Wisconsin Department of Natural Resources drinking water standards are available.

Source: U. S. Geological Survey and SEWRPC.

Movement of Pollutants Into and Through Aquifers: Pollutants may enter aquifers by continuous or intermittent seepage through pervious material. In the Menomonee River basin, natural recharge of the shallow aquifer occurs primarily in the spring and summer seasons as evidenced by water level records in unpumped wells. Pollutants may be injected directly into an aquifer through unsealed wells, a process which may include the transfer of pollutants from the shallow aquifer to the deep aquifer. Pollutants can also reach the water table rapidly if they enter through creviced limestone or dolomite exposed in quarries or at natural outcroppings. In most cases, however, a pollutant seeps slowly through the soil, taking days or even months to reach the water table, depending on the amount of recharge, the depth to the water table, and the character of the overlying soil and rock. Once the contaminant enters the aquifer, it moves with the groundwater; and its velocity and direction of travel is determined by the hydraulics of the groundwater system.

From a source of seepage, a pollutant generally moves downward to the water table, or zone of saturation, and then moves laterally down the hydraulic gradient toward a discharge area, such as a surface stream or an active pumping area. The velocity at which it moves in the subsurface depends upon the permeability of the materials and the hydraulic gradient. Groundwater velocities may range from as much as five feet per day to as little as five feet per year. In uniform materials, dispersion and dilution of the pollutant occurs as it moves toward the discharge area. The approximate flow path of a contaminant from any site may be determined from a potentiometric surface map. Detailed site studies are required to define precise flow paths at any locality.

Map 76 shows a portion of the potentiometric map of the shallow dolomite aquifer in the Menomonee River watershed. Generally, water in an aquifer moves at right angles to the potentiometric contours. A contaminant starting at point "A" in the City of Brookfield, for example, will follow a curved path southeasterly into the Village of Elm Grove. It could enter a pumping well anywhere along the way.

Although contaminants usually move slowly through an aquifer, rapid movement is possible, as illustrated by a test conducted near Sussex in 1965 by the Waukesha County Health Department in which contaminants moved more than 500 feet per day through the creviced bedrock. A condition such as this can pose a particularly severe public health problem if the contaminated aquifer is used as a source for drinking water since, at the high flow velocities involved, harmful micro-organisms may not remain in the water flow long enough to die before ingestion by humans.

Soils and granular mineral deposits, such as sand, silt, and clay, can assimilate and naturally purify some waste materials through bacterial action, base exchange processes, selective adsorption, for filtering. Organic wastes often decompose and are removed by filtration within relatively short distances of their source, whereas soluble minerals, synthetic detergents, phenols, and similar substances persist. In fissured rocks such as dolomite, however, the capacity to assimilate wastes may be small because some openings are large and transmit unaltered wastes for long distances.

Pumping disrupts the natural pattern of groundwater movement and diverts water from a large area toward the well. Pollutants within the area of pumping influence may thus be induced to flow toward, and eventually discharge to, the well. The probability of pollution of the well supply is high if the well is close to the source of pollution. The degree of pollution depends upon the hydraulic properties at the site and factors such as the type, toxicity, concentration, quantity of pollutant, and the duration of its contact with geologic environment. At each location, therefore, many factors must be determined to evalute the pollution hazard.

Examples of pollution of domestic supply wells by seepage of effluent from septic tanks have been reported by health officials to have occurred in the watershed portions of the City of Brookfield and Village of Menomonee Falls in Waukesha County. Furthermore, instances of accidental pollution of domestic supply wells have been documented. A train derailment resulting in an acid spill rendered unsafe the wells of residents in the small unincorporated community of Beulah Station in Walworth County.

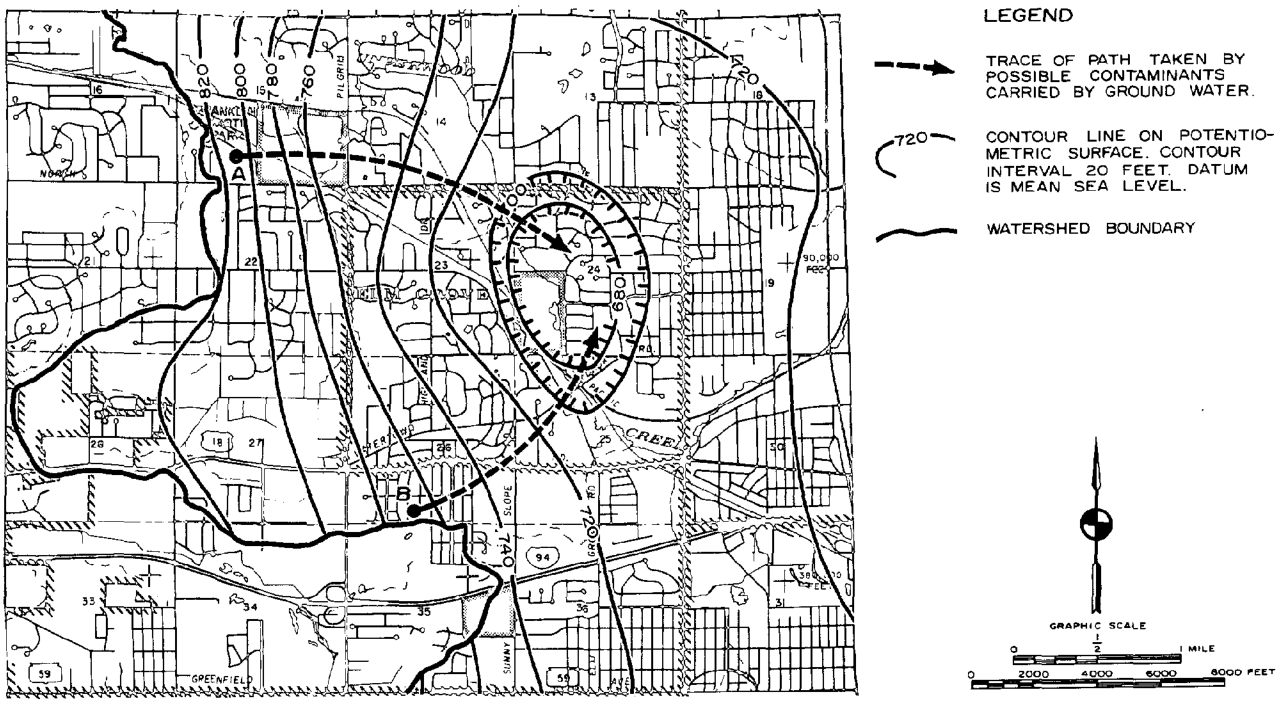
While, shallow domestic wells are susceptible to pollution from all types of contaminants, pollution of domestic supply wells by seepage of effluent from septic tanks is a much more common occurrence within the Region. Such pollution generally results from spacing wells and septic tanks too closely for the existing hydrogeologic conditions. It also is aggravated by improperly functioning septic tanks and by poorly sealed well casings, which allow vertical movement of groundwater around the casing. Areas in which fissured rocks are only thinly buried are particularly susceptible. Pollution from septic tank effluent may be avoided or reduced by proper location, design, and construction of septic tanks and wells, adequate lot sizes, or development of community sanitary sewerage systems and public water-supply systems.

Potential Pollution Problems: The pollution of groundwater is a particularly serious potential problem in certain areas of the Menomonee River watershed. An increased probability of pollution exists in areas where:

1. Residential land uses are concentrated and private onsite sewage systems are used.
2. The water supply is obtained from shallow wells pumping water from just beneath the water table.
3. The water table is close to the land surface.
4. The soil is highly pervious and pollutants move readily through the soil.
5. The aquifer is creviced dolomite bedrock that extends to or near the land surface.

Map 76

POTENTIOMETRIC MAP OF THE SHALLOW AQUIFER SHOWING THE GENERAL DIRECTION OF GROUNDWATER MOVEMENT IN A PORTION OF THE MENOMONEE RIVER WATERSHED



As shown on the map, water in an aquifer generally moves at right angles to the potentiometric contours. A dissolved pollutant entering the aquifer may be expected to move with the groundwater laterally down the hydraulic gradient toward a discharge area, such as a surface stream or active pumping area. The possibility of pollution of a well supply is high if the well is close to the source of pollution.

Source: U. S. Geological Survey and SEWRPC.

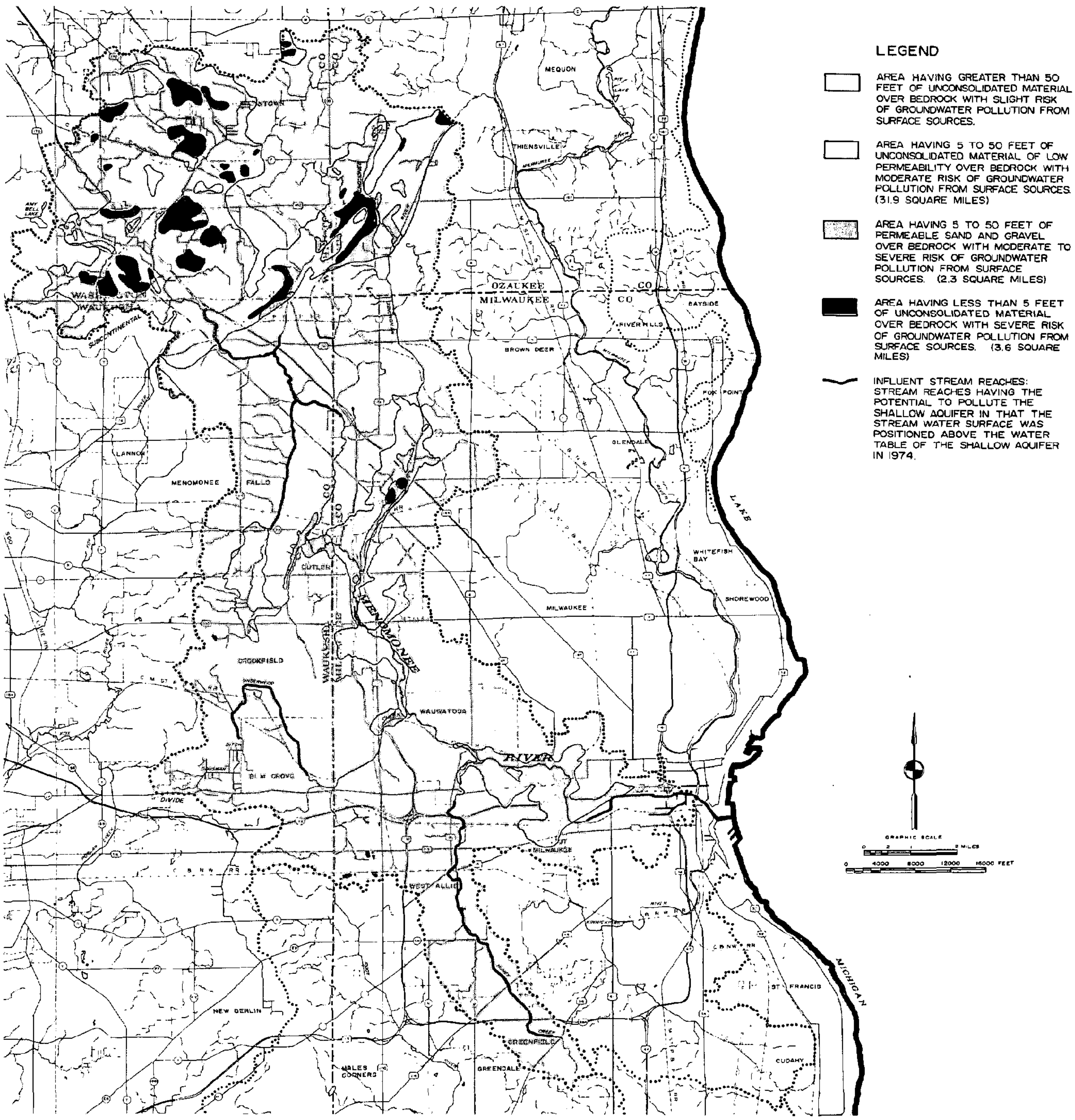
A subsequent section of this chapter dealing with watershed water supply problems discusses the potential for pollution of private wells in the western and northern portions of the watershed. This aesthetically undesirable and potentially hazardous situation results from the use of private wells and onsite waste disposal systems in areas overlain by soils unsuited for the latter.

Pollution of the Dolomite Aquifer: The glacial deposits overlying the dolomite bedrock in most of the watershed are sufficiently thick to prevent direct pollution of the dolomite aquifer. Within areas where the bedrock is covered by less than 50 feet of unconsolidated material, there is a particularly high potential for pollution of the dolomite aquifer. This potential is dependent on both the thickness and the characteristics of the unconsolidated material. Map 77 identifies that portion of the watershed having less than 50 feet of unconsolidated material over the dolomite bedrock. These areas cover a total of 37.8 square miles—28 percent of the watershed—and are concentrated primarily in the northwestern corner of the watershed with secondary areas being located along the Menomonee River in the middle and lower sections of the watershed. About 31.9 square miles, or 23 percent, of the total area having potential for pollution of the dolomite aquifer are overlain with 5 to 50 feet of unconsolidated material of low permeability thereby presenting only a moderate risk of groundwater pollution from surface sources. Approximately 2.3 square miles, or 2 percent, of the 37.9-square-mile area having potential for pollution of the dolomite aquifer are covered with 5 to 50 feet of permeable sand and gravel and therefore, the risk of groundwater pollution is categorized as moderate to severe. Finally, approximately 3.6 square miles, or 3 percent, of the total area having potential for pollution of the dolomite aquifer are overlain with less than five feet of unconsolidated material thereby presenting a severe risk of groundwater pollution from surface sources.

Groundwater in these areas may be readily subject to pollution because the deposits transmit water readily. Water may move at a rate of up to 10 feet per hour through some of these highly permeable soils. Bacteria, virus, or other infectious agents can be quickly transported to drinking water supplies through such soils in a time interval so short that very few of the microorganisms would die off or be filtered out.

Map 77

POTENTIAL AREAS OF SAND AND GRAVEL AQUIFER AND DOLOMITE AQUIFER POLLUTION IN THE MENOMONEE RIVER WATERSHED



Within areas where the bedrock is covered by less than 50 feet of unconsolidated material, there is a high potential for pollution of the dolomite aquifer. As shown on the map, slightly more than one-fourth of the watershed is overlain by less than 50 feet of protective unconsolidated materials.

Source: U. S. Geological Survey and SEWRPC.

Influent Streams: A reach of a stream is influent or loses water to groundwater, if it contributes water to the zone of saturation. The upper surface of such a stream stands higher than the water table or other potentiometric surface of the aquifer to which it contributes and, therefore, the hydraulic head diminishes with distance from the stream. In contrast, an effluent stream has a lower hydraulic head than the aquifer through which it passes and therefore receives water from the zone of saturation. At any given time, a stream may, in certain parts, be influent; in other, effluent; and in still others, neither. The significance of the influent stream reach is that it provides a mechanism whereby pollutants being carried in the stream may be transmitted to the underlying groundwater and therefore to users of that water. Heavily pumped wells located near streams may induce polluted surface water to move into the groundwater supply and, eventually, into the wells. The existence of influent streams and the direction of groundwater movement from these streams can be determined by analyses of the potentiometric surface of the aquifer and its relationship to the approximate elevation of the water surface of the stream.

An analysis of stream surface elevations and the potentiometric surface of the dolomite aquifer and glacial deposits as they existed in the Menomonee River watershed in 1973 and as shown on Map 77, reveals the probable existence of several influent stream reaches. Approximately 22 miles of the watershed stream system may be influent in that the potentiometric surface of the shallow aquifer in the vicinity of these streams is positioned below the surface of the stream. As shown on Map 77, the potentially influent stream reaches consist of 3.0 miles of the Lower Menomonee River, 4.9 miles of the Upper Menomonee River, 3.7 miles of Underwood Creek, 6.8 miles of Honey Creek, 3.0 miles of Lilly Creek, 0.4 miles of Nor-X-Way Channel, and 0.6 miles of Dousman Ditch. The influent stream reaches are generally located within or near depressions in the potentiometric surface that appear to be induced by pumping from the shallow aquifer.

Concluding Statement: Potential Problem Areas: The shallow sand and gravel aquifer and the dolomite aquifer are more susceptible to contamination by human activity in the watershed than is the deep sandstone aquifer. The most serious potential groundwater pollution problem in the watershed is that associated with the use of private wells and septic systems on soils not well suited for the latter. Inasmuch as 28 percent of the dolomite aquifer in the watershed is overlain by less than 50 feet of unconsolidated material, a potential exists for pollution of the heavily used dolomite aquifer. The watershed contains approximately 22 miles of influent stream reaches thereby providing another potential means for polluting the sand and gravel aquifer and the dolomite aquifer. In summary, then, although the groundwater in the Menomonee River watershed is generally of good quality for domestic and commercial-industrial uses and although no serious groundwater pollution problems are known to exist, there is a very real potential for pollution problems to develop in the sand and grave aquifer and in the dolomite aquifer.

WATER SUPPLY PROBLEMS

As of 1970, about 56 square miles, or 77 percent of the urbanized area of the watershed, 41 percent of the total watershed area, and 85 percent of the total watershed population, were served by publicly owned water supply systems. The remaining 15 percent of the watershed population received its water supply from privately owned water supply systems or from individual wells.

The eight public water utilities that serve the watershed consist of four utilities that utilize Lake Michigan—the Milwaukee Water Works, the Wauwatosa Water Works, the West Allis Water Utility, and the Greendale Sewer and Water Utility—and four utilities that draw on the groundwater resource—the Menomonee Falls Water Utility, the Butler Water Utility, the Germantown Water Utility, and the Brookfield Water Utility. The service areas of these public utilities are identified on Map 13 while population and service area data are set forth in Table 67 and illustrated graphically in Figure 63.

Public Water Supply Systems Using Lake Michigan

Almost 80 percent of the watershed population receives Lake Michigan water which, after use, is discharged to the sanitary sewer system in the Milwaukee County portion of the watershed from which it is transported back out of the watershed for treatment before being returned to the lake. The average daily supply of Lake Michigan water to the Menomonee River watershed is estimated at 48 million gallons.[42] Inasmuch as the water supply system of the Milwaukee County portion of the watershed is not an integral part of the hydrologic-hydraulic system of the watershed it was not considered further in the watershed study except as an alternative means of providing water supply to those areas of the watershed in Ozaukee, Washington, and Waukesha Counties that do not have adequate public water supply systems.

Public Water Supply Systems Using Groundwater

About 6 percent of the watershed population receives groundwater provided by four public water utilities which supply a total average flow of about 3.76 million gallons per day to areas within and outside of the watershed. In-watershed use of water from the groundwater utilities is estimated at 2.0 million gallons or about 4 percent of the in-watershed use of Lake Michigan water. Officials of each of the four utilities using groundwater were contacted under the Menomonee River watershed planning program to obtain pumpage data and other information about the systems and to ascertain the existence of water supply problems—either quantity or quality—that may be intermunicipal in nature.

Village of Germantown Water Utility: This utility operates three wells—two in the deep or sandstone aquifer and one in the shallow or dolomite aquifer. A total of 79.6 million

[42] *As an aid to visualizing the rate of use of Lake Michigan water in the watershed, the average daily supply of water from the Lake is approximately equal to the average daily discharge of the Menomonee River watershed.*

Table 67

SOURCE OF DOMESTIC WATER SUPPLY IN THE MENOMONEE RIVER WATERSHED: 1970

Type of Water System	Source of Water	Name of Utility	Estimated Population Served in the Watershed	Percent of Watershed Population	Estimated Service Area (square miles)
Public	Lake Michigan	Milwaukee Water Works	181,788	52.2	31.38
		Wauwatosa Water Works	57,245	16.5	13.12
		West Allis Water Utility	37,536	10.8	4.98
		Greendale Water and Sewer Utility	492	0.1	0.25
		Subtotal	277,061	79.6	49.73
Public	Groundwater	Menomonee Falls Water Utility	15,608	4.5	4.02
		Butler Water Utility	2,151	0.6	0.79
		Germantown Water Utility	1,965	0.6	0.99
		Brookfield Water Utility	710	0.2	0.31
		Subtotal	20,434	5.9	6.11
Private[a]	Groundwater	--	50,670	14.5	16.83[b]
		Total	348,165	100.0	72.67

[a] *In addition to wells at individual residences, this includes the following five private water utilities: Colony Homes Co-op and Van Dyke Water Co-op in the City of West Allis, Marion Heights in the Village of Elm Grove, and Riverview Manor Co-op and Silver Spring Terrace in the Village of Menomonee Falls. The first two private water utilities were connected to the City of West Allis Water Utility in 1971.*

[b] *Estimated by subtracting the area served by public water supply (55.84 square miles) from the total urban land use in the watershed (72.67 square miles).*

Source: SEWRPC.

gallons was pumped in 1974 for an average of 218,000 gallons per day. The peak daily pumpage of 519,000 gallons occurred on July 19 of that year. The Germantown Water Utility is not presently experiencing any quantity problems such as declining water levels. The principal water quality problems are hardness and high iron concentrations, both typically associated with groundwater sources.

The Village intends to continue to rely on groundwater as its source of supply and will add additional wells or pumping capacity as the need arises. The Village of Germantown is, however, awaiting action on the final report from a consulting firm[43] on the feasibility of an intercommunity water supply system before proceeding with any major additions to its water supply system. The report is an outgrowth of a recommendation in the Commission's Milwaukee River watershed plan that the City of Mequon and the Villages of Bayside, River Hills, and Thiensville jointly create a municipal water supply system utilizing Lake Michigan as a source of supply.

[43] *Consoer, Townsend and Associates, Engineering Report on Sources of Water Supply for Mequon, Brookfield, Bayside, River Hills, Thiensville, Menomonee Falls, and Germantown, Wisconsin, March 1976.*

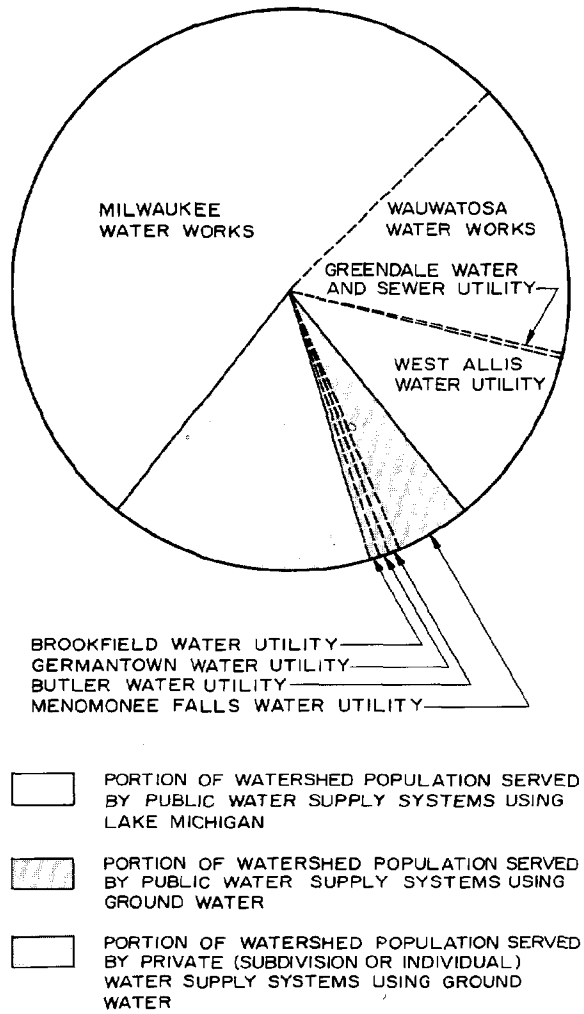
The following alternative water supply systems were examined: 1) expand and integrate the existing groundwater system, 2) purchase water from the City of Milwaukee, and 3) develop an intermunicipal water supply system using Lake Michigan as a source. The report recommends that the seven communities form a Water Commission and that they select alternative 2 unless presently unfavorable construction cost conditions change in the very near future in which case alternative 3 is recommended.

Village of Menomonee Falls Water Utility: Four wells are operated by this utility—three in the sandstone aquifer and one on the dolomite and sand and gravel aquifers—and in 1974 a total of 823.6 million gallons of water was provided by the system. The average daily pumpage was 2,256,000 gallons while the maximum daily pumpage, which occurred on July 19, 1974, was 3,345,000 gallons. The Menomonee Falls water utility is not experiencing any serious quantity problems although declining water levels have been observed. As was the case with the Village of Germantown system, the principal water quality problems are hardness and high iron content.

Immediate plans call for continued reliance on groundwater as the source of water supply with the utility planning to eventually extend water supply service to the entire Village area. The Village is awaiting final action on

Figure 63

SOURCE OF DOMESTIC WATER SUPPLY
IN THE MENOMONEE RIVER WATERSHED: 1970



NOTE: THE CIRCLE REPRESENTS THE TOTAL 1970 POPULATION (348,165) OF WATERSHED

Source: SEWRPC.

the aforementioned consultant study of intermunicipal water supply alternatives before embarking on any major additions to the existing water supply system.

Village of Butler Water Utility: This utility operates one well that extends into the sandstone aquifer. In 1974, a total of 238.5 million gallons of water pumped—an average of 653,500 gallons per day—and a peak daily pumpage of 823,000 gallons was reported on August 16 of that year. The Village is not experiencing any quantity problems and does not expect any inasmuch as the Village has essentially reached its growth limit and the water supply system is currently operating at about one-third of the design capacity. In addition, as a contingency measure, the Village has an arrangement to purchase water from the Milwaukee Water Works. As was the case with the above two groundwater utilities, hardness and excessive iron characteristic of groundwater are the only water quality problems experienced by the Village. For the immediate future, the Village of Butler intends to continue to rely on groundwater as its source of supply.

City of Brookfield Water Utility: As of mid-1975 the City of Brookfield water utility operated a total of 19 wells, six of which extend into the sandstone aquifer and 13 of which draw on the dolomite aquifer. A total of 302.0 million gallons of water was pumped from the wells in 1974 at an average rate of 827,400 gallons per day with a peak daily pumpage of 2,200,000 gallons occurring on July 22, 1974.

The City is not experiencing any water quantity problems. As for quality, the only problems noted to date are hardness and high iron levels. Immediate plans call for continued reliance on the groundwater supply to meet increasing needs. The City of Brookfield has a new policy which requires subdivisions containing 40 or more lots to be served by a groundwater system which is incorporated into the City's municipal system. As was the case with the Germantown and Menomonee Falls water utilities, the City of Brookfield Water Utility is awaiting final action on the consultants' report on intermunicipal water supply alternatives before initiating any major additions to the water supply system.

Concluding Statement—Groundwater Utilities: Inventories conducted under the watershed planning program revealed that none of the four public water utilities utilizing groundwater is experiencing serious water supply problems with respect to either the quantity or quality of water available from the well systems or from falling groundwater levels. In addition, none of the groundwater utilities anticipates water supply problems in the immediate future.

The absence of problems now or in the immediate future should not lead to complacency over long-range reliance on groundwater under conditions of increased pumpage. Analyses with a simulation model of the sandstone aquifer[44] indicate the potentiometric surface of the deep aquifer will be drawn down an additional 250 to 400 feet

[44] *H. L. Young, "Digital Computer Model for Management of the Sandstone Aquifer in Southeastern Wisconsin," Preliminary Open File Report, U. S. Geological Survey, Madison, Wisconsin, June 1975. This simulation model of the deep sandstone aquifer was developed by the U. S. Geological Survey in a cooperative program with the major public groundwater utilities in southeastern Wisconsin, the Commission, and the Wisconsin Geological and Natural History Survey. Final documentation of the model may be found in SEWRPC Technical Report No. 16, Digital-Computer Model of the Sandstone Aquifer in Southeastern Wisconsin, April 1976.*

in the Menomonee River watershed by the year 2000. Future drawdowns, the largest of which are expected to occur in the southwestern portion of the watershed, reflect increased regional groundwater use but are primarily attributed to large pumpage projections in the Waukesha-New Berlin area of Waukesha County.

Partly because of the absence of serious existing groundwater quality or quantity problems and the pending action on recommendations contained in the recently completed consultants' study of intermunicipal water supply system arrangements, those areas in the watershed served by public utilities using groundwater were not considered further in the watershed study except as they might offer alternative means of providing water-supply service to those areas in the watershed that are not yet served by public water supply. Equally important, because of the relatively small size of the Menomonee River watershed and the large number of civil divisions located in and near the watershed, municipal water supply planning should not be artificially confined within the watershed but should instead encompass all those portions of the Milwaukee-Metropolitan area that now have or may develop water supply problems. Long-range water supply planning in general, and use of groundwater in particular, should be conducted, utilizing a regional approach that properly incorporates the areawide characteristics of this water supply resource.

Potential Water Supply Pollution Problems in Urban Areas Not Served by Public Water Supply and Sanitary Sewer Systems

Pollution of domestic water supplies is both an existing and potential problem in that portion of the watershed that relies on both private groundwater supplies and onsite sewage disposal systems. Map 78 identifies those developed urban areas that, as of 1970, used private groundwater systems and were not served by public sanitary sewer systems. These areas encompass a total of about 12 square miles—16 percent of the urbanized portion of the watershed—and are located primarily in the City of Brookfield and the Village of Menomonee Falls with secondary dispersed areas located in the Village of Germantown and the City of Mequon.

The conjunctive use of private water supplies and onsite sewage disposal systems can lead to pathogenic and aesthetic pollution if the underlying soils are not suited to the effective functioning of onsite waste disposal systems. If the soils are incapable of adequately absorbing and transmitting the discharge from the septic system tile fields, the soil tends to become saturated, private shallow wells may become polluted with domestic waste, and sanitary sewage may accumulate in low areas and storm water drainage swales and may enter storm sewers and surface water courses. Map 78 shows those areas that rely on private groundwater supplies and are also underlain with soils exhibiting severe limitations for the utilization of onsite waste disposal systems on lots one acre or less in size. The map clearly illustrates how most of the urban development—about 88 percent—relying on the combination of private groundwater and onsite sewage disposal systems has occurred on soils not suited for onsite sewage disposal. As a result, recent years have produced examples of aesthetic pollution including the generation of offensive odors and septic tank system discharge appearing in low areas and drainage swales, as shown on Map 78. More importantly, such conditions pose a threat to public health in these areas because of the potential of direct contact with the septic tank system discharge on the ground surface or as a result of pollution of the private groundwater supplies.

The ultimate resolution of these existing and potential water supply pollution problems as recommended in the adopted regional sanitary sewerage system plan is provision of sanitary sewer service to essentially all of those portions of the City of Brookfield and the Village of Menomonee Falls that lie within the Menomonee River watershed. Such service would eliminate the potential for pathogenic and aesthetic pollution from malfunctioning onsite sewage disposal systems in that portion of the watershed. The regional sanitary sewerage system plan also recommends that sanitary sewer service be provided to portions of the Village of Germantown and the City of Mequon which would similarly eliminate the potential pollution problems that now exist as a result of the use of both private water supplies and onsite sewage disposal systems in these communities.

Self-Supplied Industrial and Commercial Data Use

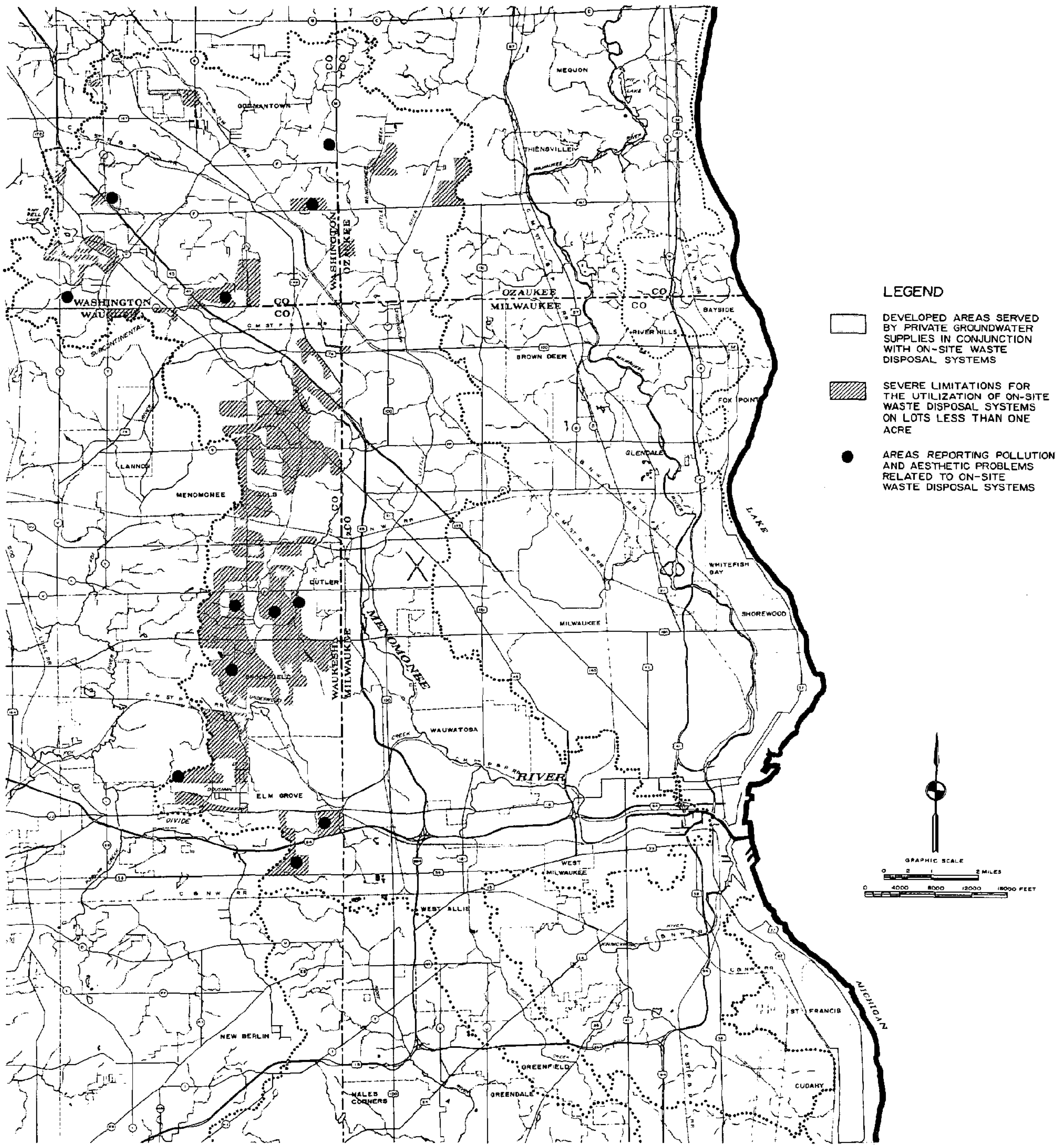
Some commercial-industrial water users within the watershed are self-supplied in that they obtain all or part of their water needs from private wells or directly from the surface waters rather than relying entirely on water from municipal water supply systems. Most of the users of self-supplied water draw on groundwater sources rather than surface water sources primarily because of the higher quality of the former source. Under the inventory phase of the Menomonee River watershed planning program, information was obtained from selected self-supplied water users in order to determine the types of uses made of the water and to identify any serious quantity or quality problems that may exist.

Groundwater Use: As discussed in Chapter X of this volume, and set forth in Table 100, a total of 22 nonmunicipal high capacity well permits—in excess of 100,000 gallons per day or 70 gallons per minute—are known to have been issued as of 1975 in the Menomonee River watershed. Of this total, eight are located in Milwaukee County, one in Ozaukee County, two in Washington County, and 11 in Waukesha County. The most common use of these wells is for industrial-commercial purposes with 14 of the wells being categorized as to that type of use. Five of the 22 wells are used for irrigation-domestic purposes and the remaining three are pumped for fire protection purposes.

Self-supplied industrial-commercial groundwater users in the watershed utilize the water primarily for a variety of cooling purposes. For example, the Miller Brewing Company in the City of Milwaukee uses self-supplied groundwater for ammonia condensing in a refrigeration process and the Gehl Guernsey Farms, Inc., a dairy located in the Village of Germantown, uses the water to condense milk vapor. Other uses of self-supplied groundwater include washing processes and fire protection.

Map 78

AREAS IN THE MENOMONEE RIVER WATERSHED WITH EXISTING OR POTENTIAL POLLUTION PROBLEMS ATTRIBUTABLE TO USE OF PRIVATE WATER SUPPLIES AND ONSITE WASTE DISPOSAL SYSTEMS: 1970



The conjunctive use of private wells and onsite sewage disposal systems can lead to pathogenic and aesthetic pollution of the water supply if the underlying soils are not suited to the effective functioning of the onsite waste disposal systems. If the soils are incapable of adequately absorbing and treating the discharge from the septic system tile fields, the soil tends to become saturated, private shallow wells may become polluted with domestic waste, and sanitary sewage may accumulate in low areas and storm water drainage swales and may enter storm sewers and surface water courses.

Source: U. S. Geological Survey and SEWRPC.

uses self-supplied groundwater for ammonia condensing in a refrigeration process and the Gehl Guernsey Farms, Inc., a dairy located in the Village of Germantown, uses the water to condense milk vapor. Other uses of self-supplied groundwater include washing processes and fire protection.

Six major self-supplied commercial-industrial users of groundwater were contacted under the watershed planning program in order to determine if serious quantity or quality problems existed or appeared to be developing. The results of this survey are summarized in Table 68 and reveal that no significant quantity problems were being experienced, such as excessive drawdowns. The only water quality difficulties encountered consisted of hardness and high iron which are characteristic of groundwater compared to surface water.

Surface Water Use: A small number of self-supplied industrial-commercial water users rely on surface water for specialized water uses to supplement water obtained from municipal systems. Although this source is readily available to potential riverine area water users, the overall low quality of the water coupled with unpredictable diurnal, weekly, and seasonal changes in water quality and quantity mitigate against the use of surface water.

Two notable self-supplied surface water users are the Falk Corporation and the Wisconsin Electric Power Company, both of them located in the Menomonee River industrial valley in the City of Milwaukee. As of about 1970, the Falk Corporation withdrew about 38.0 million gallons of water per year from the Menomonee River, used it for cooling purposes and returned it to the stream. This flow, which amounts to only about 0.2 percent of the annual discharge of the Menomonee River, is withdrawn from behind a low head dam that marks the upper end of the Menomonee River estuary. The Wisconsin Electric Power Company's Valley Electric Power Generating Station uses the Menomonee River as a source of condensor cooling water. Water is taken from the Menomonee River and discharged back to the river via the South Menomonee Canal at an average annual rate of about 95.0 million gallons. This flow, which is equivalent to approximately 0.5 percent of the annual discharge of the Menomonee River watershed, probably does not consist entirely of water flowing directly from the watershed. The power company intake is located only 0.7 miles from the confluence of the Menomonee and Milwaukee Rivers and therefore may draw some water from the Milwaukee River and Lake Michigan. The water withdrawn by the power company is screened and chlorinated prior to pumping it through the condensors.

The Village of Elm Grove has installed a movable gate at the downstream end of the 0.10 mile long conduit that conveys Underwood Creek beneath the shopping center parking lot south of Watertown Plank Road. The gate, when closed, provides a temporary, approximately 300,000 gallon reservoir maintained for fire-fighting purposes in the business-commercial area of the village.

Table 68

INFORMATION ON SELECTED MAJOR SELF-SUPPLIED INDUSTRIAL-COMMERCIAL USERS OF GROUNDWATER IN THE MENOMONEE RIVER WATERSHED: JULY 1975

User	Location	Estimated Annual Pumpage in Million Gallons	Uses	Quantity Problems	Quality Problems	Comment
Miller Brewing Company	City of Milwaukee	310	Ammonia condensing	None	Hardness, high iron, some hydrogen sulfide	No treatment
Gehl Guernsey Farms, Inc.	Village of Germantown	125	Milk vapor condensing	None	None	No treatment
Wisconsin Packing Company	Village of Butler	18	Fire protection and general operations	None	Hardness	Water is softened
Butler Lime and Cement Compant	City of Wauwatosa	3	Ready mix concrete	None	None	No treatment
Allis Chalmers Corporation	City of West Allis	120	Drinking and sanitation	None	High iron	Water is treated for iron removal
Kearney and Trecker Corporation	City of West Allis	60	General operations	None	Hardness, hydrogen sulfide	Water is chlorinated to reduce hydrogen sulfide and softened

Source: SEWRPC.

Concluding Statement—Self-Supplied Water Users: Based on information collected under the watershed planning program, self-supplied users of groundwater are authorized to extract a large quantity of water from the watershed aquifers. This pumpage is concentrated in the Milwaukee County portion of the watershed. Information obtained from the four water utilities in the watershed relying on groundwater indicates no apparent problems as a result of industrial-commercial water use in the basin. Moreover, it appears as though self-supplied industrial-commercial users of groundwater are not encountering any quantity or quality problems except for the expected hardness and high iron typical of groundwater in the southeastern Wisconsin planning area. Surface water is used by only a few self-supplied industrial-commercial users and the uses are such that quantity problems do not exist and quality problems are readily resolved.

In summary then, self-supplied industrial and commercial water use in the Menomonee River watershed does not pose any known problems of intermunicipal or watershedwide concern. Because of the absence of problems and because of the contingency provided by the eight municipal water utilities in the watershed, self-supplied industrial and commercial water use was not further explicitly addressed in the Menomonee River watershed planning program.

SUMMARY

In an urban and urbanizing setting like the Menomonee River watershed, human activities affect, and are affected by, the quality of the surface and ground waters. Therefore, a comprehensive watershed planning program for such a basin must assess water quality conditions and, if pollution problems exist or are likely to develop, must address the abatement of such problems in the plan preparation phase of the work.

This chapter documents historic and existing water quality and pollution problems in the watershed to serve as the basis for the design and analysis of alternative water quality control plan elements. In particular, the chapter discusses the concepts of water quality and pollution; describes the characteristics and significance of key water quality parameters; summarizes surface water quality objectives and supporting standards; discusses municipal and private water supply systems with emphasis on identification of existing or potential intermunicipal quantity and quality problems; documents the type, location, and characteristics of wastewater sources; describes the historic and existing quality of the surface and groundwater resources; and discusses the use of Lake Michigan water and groundwater by municipal water utilities and by self-supplied water uses.

"Water quality," as applied to surface and ground water resources, encompasses the physical, chemical, and biological characteristics of the water. Water is deemed to be polluted when foreign substances caused by or related to human activity are in such a form and concentration so as to render the water unsuitable for a desired beneficial use. Surface or ground water pollution may be classified as one or more of the following seven types depending on the nature of the substance causing the pollution; toxic pollution, organic pollution, nutrient pollution, pathogenic pollution, thermal pollution, sediment pollution, and aesthetic pollution. Water pollution is relative in the sense that whether or not a particular water resource is polluted is a function of the intended use of that water resource, that is, water may be polluted with respect to some uses and not polluted with respect to others.

Many parameters or indicators are available for measuring and describing water quality. Some of the more important indicators used in the analysis of water quality conditions in the Menomonee River watershed are: temperature; dissolved solids; undissolved solids; hydrogen ion concentration; chloride; dissolved oxygen; carbonaceous biochemical oxygen demand; nitrogenous biochemical oxygen demand; coliform bacteria; nutrients; aquatic flora and fauna; heavy metals and organic pesticides; iron and manganese; sodium; calcium, magnesium, and hardness; bicarbonate, carbonate, and alkalinity; sulfate; fluoride; nitrate; and nitrite.

Water quality standards supporting the water use objectives for the watershed's surface water systems provide a scale against which historic and existing water quality can be judged. The established water use objectives require that all of the surface waters satisfy minimum standards and that most of the stream system be suitable for recreational use and propagation of fish and aquatic life. Exceptions include Honey Creek, the south branch of Underwood Creek, the lower portion of Underwood Creek, and the extreme lower reaches of the Menomonee River, all of which are in the less stringent restricted use category.

The following types of pollution sources have been identified in the Menomonee River watershed: municipal sewage treatment plants, sanitary and combined sewerage system flow relief points, industrial discharges, urban storm water runoff and agricultural and other rural runoff. Varied sources of field data extending back to 1951 were used to assess the quality of the watershed surface and ground water and to determine the probable cause of the polluted conditions that do exist in the basin. These sources of water quality data include: Wisconsin Department of Natural Resources basin surveys, the SEWRPC 1964-1965 surface water quality study, the SEWRPC-DNR 1968-1974 continuing water quality monitoring program, a 1968-1969 watershedwide phosphorus study, a 1972 creosote investigation on the Little Menomonee River, preliminary 1973-1974 IJC Menomonee River Pilot Watershed Study, and data from three 24-hour synoptic surveys conducted under the Menomonee River watershed planning program.

Five municipal sewage treatment facilities existed in the watershed when the planning program was initiated in 1972—the Village of Germantown Old Village and County Line Road plants, the Village of Menomonee Falls Pilgrim Road and Lilly Road plants and the Village of Butler overflow-chlorination facility. The Germantown County Line Road facility was permanently removed from service on November 2, 1973. All of the remaining four municipal sewage treatment plants in the Menomonee River watershed will cease discharging to the Menomonee River watershed stream system about 1981.

Sanitary sewage also enters the surface water system of the Menomonee River watershed through five types of sewerage system flow relief devices: combined sewer outfalls, crossovers, bypasses, relief pumping stations, and portable pumping stations. A total of 25 combined sewer outfalls plus 102 other flow relief devices are known to exist in the watershed with 80 percent of 127 flow relief devices discharging to the Menomonee River. Forty percent of the flow relief devices, including all of the 25 combined sewer outfalls, are located within the Milwaukee County portion of the watershed. The 27-square-mile Milwaukee Metropolitan area combined sewer service area, which includes a 10.7-square-mile area tributary to the Menomonee River, is the subject of a two-year preliminary engineering study by a consulting firm directed at the abatement of combined sewer overflows. This study, which is scheduled for completion in 1977, is intended to build upon previous work by the Regional Planning Commission under the Milwaukee River watershed planning program and is to result in firm recommendations for constructing combined sewage conveyance, storage, and treatment facilities so as to abate pollution from the entire combined sewer service area.

Industrial discharges, consisting primarily of cooling and process water, directly and indirectly enter the watershed stream system. A total of 44 industrial discharges—half are cooling water—are known to exist within the watershed with over three-fourths discharging to the Menomonee River and about 85 percent being located in Milwaukee County. Although these discharges probably vary markedly in quality, very little data are currently available, a deficiency that will be rectified with the continued implementation of the Wisconsin Pollution Discharge Elimination System.

Diffuse or non-point source pollution consists of various discharges of pollutants to the surface waters that cannot be traced to specific discrete sources. Such pollution is carried from the rural and urban areas of the watershed to the surface waters by means of direct runoff from the land and by interflow during and after runoff events as well as by baseflow—groundwater discharge—between such events. The synoptic water quality surveys revealed relatively high phosphorus levels in land surface runoff from agricultural and separately sewered areas during a rainfall event. Some fecal coliform bacteria counts in water flowing from such areas exceeded the level specified for recreational use. Total biochemical oxygen demand was found to be similar in rural areas and in separately sewered urban areas, with the highest values—about 10 mg/l—being reported for the lowest flow periods. A positive aspect of runoff from the land surface as revealed by the synoptic surveys is a relatively high dissolved oxygen level which is then made available in the stream system for oxidation of organic materials. It is estimated that erosion of sediment from the land surface of the Menomonee River watershed results in the transport of an average of 97.5 tons per square mile per year—13,400 tons per year—of sediment from the basin by the Menomonee River. This relatively high value apparently reflects the urbanizing nature of the watershed. It is further estimated that most of the sediment annually carried from the watershed is deposited in the estuary thereby necessitating periodic maintenance dredging to maintain navigability depths required for commercial ships. Excessive sediment loads also may be expected to cause water quality problems and unstable channel conditions.

An examination of Menomonee River watershed stream system water quality data for the period 1951 through 1974 reveals that the surface waters are severely polluted. Of the seven possible categories of pollution, six—toxic, organic, nutrient, pathogenic, sediment, and aesthetic—are known to exist in the Menomonee River watershed. The surface water pollution in the watershed is widespread in that it occurs on the Little Menomonee River, Underwood Creek, Honey Creek, and Little Menomonee Creek, in addition to the Menomonee River. This clearly indicates that pollution problems may not be solely attributed to effluent from municipal sewage treatment plants or other point sources. The practical consequence of these polluted conditions is to severely restrict the use of the watershed's stream system for recreational pursuits and propagation of fish and aquatic life.

Low dissolved oxygen levels, very high fecal coliform bacteria counts, and excessive phosphorus have existed along the main stem of the Menomonee River over at least the past decade and probably for an even longer period. There also is evidence of excessive concentrations of lead, a toxic heavy metal. The Little Menomonee River exhibits high fecal coliform bacteria counts and excessive phosphorus levels. This major tributary also has occasionally contained substandard concentrations of dissolved oxygen in addition to evidence of high lead concentrations. Further, portions of this stream contain creosote in the bottom muds in sufficient concentrations to cause severe chemical burns. Observed pollution problems on the Little Menomonee Creek, a rural area tributary to the Little Menomonee River, have been limited to excessive phosphorus levels. The two urban tributaries to the Menomonee River—Underwood Creek and Honey Creek—both have exhibited occasional instances of high fecal coliform bacteria counts and excessive phosphorus levels.

Besides these overall substandard water quality conditions, Menomonee River watershed is characterized by marked diurnal fluctuations and spatial variations of water. These temporal and spatial changes are more pronounced during dry low flow periods than during times of land surface runoff and high stream flow. Dissolved oxygen levels, for example, were observed to range from very high values during the day to low, substandard values during the nighttime hours. Furthermore, while high, generally adequate dissolved oxygen concentrations occasionally occurred in the headwater areas of the Menomonee River, low substandard values were recorded in the middle and lower reaches of the river.

The most serious type of surface water pollution present in the watershed is pathogenic pollution as evidenced by the widespread occurrence of high fecal coliform bacteria counts. These fecal coliform counts, which are indicative of the presence of human and animal wastes, appear to be attributable to sanitary and combined sewer system overflows, runoff from the rural and urban land surfaces, and discharge from animal feedlots. The second most serious pollution problem is excessive nutrients, particularly phosphorus, under all flow conditions. It is estimated that only 40 percent of the phosphorus transported from the watershed by the Menomonee River may be attributable to sewage treatment plant discharge with the remaining 60 percent being attributable to other sources such as land surface runoff, sanitary sewer overflow, and feedlot discharge. The third most serious pollution problem is organic pollution reflected by occasional widespread substandard dissolved oxygen levels. This problem is most prevalent along the main stem of the Menomonee River and appears to result primarily from discharges from municipal sewage treatment plants. In addition to pathogenic, nutrient, and organic pollution, toxic pollution in the form of high lead concentrations and the presence of creosote are causes for concern, as are sediment pollution and the aesthetic pollution that pervade the watershed surface water system.

Although the adopted water use objectives for the stream system call for recreational use and propagation of fish and aquatic life throughout most of the watershed, the surface waters currently receive only minimal use because of the severe existent pollution. Improvement of surface water quality in the Menomonee River watershed so as to achieve the water use objectives will require a watershed-wide water quality management effort aimed at both point and diffuse sources of pollution.

The natural environment of the watershed has been a far more influential determinant of groundwater quality than have the effects of human activities: groundwater, in contrast to surface water, is not so vulnerable to contamination from urban and rural runoff and waste discharges. The amount and kind of dissolved minerals in groundwater differ greatly throughout the watershed and depend upon such factors as the amount and type of organic material in the soil; the solubility of rock over or through which the water moves; the length of time the groundwater is in contact with the soil and rock; and the temperature and pressure of the water.

A total of 192 groundwater quality samples from over 123 wells in and near the Menomonee River watershed were assembled and collated under the watershed study for the purpose of evaluating the quality of the groundwater resource. With respect to its use as drinking water, the sand and gravel aquifer may yield water containing iron and manganese in excess of the recommended standards. In addition, water from this aquifer is considered "hard" for general domestic use and some industrial-commercial uses.

Water drawn from the dolomite aquifer for drinking water purposes may be expected to contain iron and manganese in excess of the recommended standards for drinking water. Although water from the dolomite aquifer is considered hard for general domestic use, none of the water utilities treats the water for hardness removal. Dolomite aquifer water also is considered hard for some industrial-commercial users and, as a result, some self-supplied industrial-commercial users employ water softening processes.

With respect to its use as drinking water, wells tapping the sandstone aquifer and wells tapping both the sandstone and dolomite aquifers may be expected to yield water containing iron, manganese, and sulfate in concentrations exceeding the recommended standards. In addition, water from the sandstone aquifer is considered hard for general domestic use and for some industrial-commercial uses as is water from the combination of the dolomite and sandstone aquifers.

Seepage of domestic, municipal, industrial, and agricultural wastes into shallow groundwater may occur from many potential sources. These include, but are not restricted to: private onsite sewage disposal systems (septic tanks), refuse dumps, barnyards, cesspools and sewage lagoons, private and dry wells, influent (losing) streams, industrial spillages, leakage from community sewerage systems, and seepage from agricultural lands which are more apt to affect the shallow aquifer than the deep aquifer.

Problems involving pollution of groundwater generally are much more stubborn than problems involving surface water, because the hidden paths of groundwater contaminants cannot be easily traced. In most cases, a pollutant seeps down slowly and takes days or even months to reach the water table, depending on the amount of recharge, the depth to the water table, and the character of the overlying soil and rock. Once the contaminant enters the aquifer, it moves with the groundwater; and its velocity and direction of travel can be determined by the hydraulics of the groundwater system. Groundwater velocities normally range between five feet per day and five feet per year. As a potential pollutant moves with the groundwater, its concentration is normally reduced by dilution dispersion, adsorption or filtering by the aquifer material, and by biochemical processes.

Increased likelihood of groundwater pollution exists in residential areas using onsite waste disposal systems and private wells, in areas where the water table is close to the land surface, where the soil is highly pervious permitting the relatively fast transport of pollutants, in areas where the dolomite aquifer is creviced and extends to or near the land surface. The glacial deposits overlying the dolomite in most of the watershed are sufficiently thick to prevent direct pollution of the dolomite aquifer. There is, however, a potential for pollution of the aquifer where it is covered by less than 50 feet of unconsolidated material. Such areas cover a total of 37.8 square miles—28 percent of the watershed—and are concentrated primarily in the northwestern corner of the watershed. Influent or losing stream reaches are a mechanism whereby pollutants may be transmitted into the sand and gravel aquifer and the dolomite aquifer. An analysis of the potentiometric surface of the shallow aquifers reveals that 22 miles of the watershed stream system may be influent. The influent reaches are distributed throughout the watershed, being located on the Upper Menomonee River, the Lower Menomonee River, Underwood Creek, Honey Creek, Lilly Creek, Nor-X-Way Channel, and Dousman Ditch.

Although water from the watershed aquifers is chemically classified as hard and water from some wells contains substandard concentrations of some constituents, the overall quality of groundwater in the Menomonee River watershed is markedly superior to stream water quality. There is very real potential for pollution problems to occur in the sand and gravel aquifer and in the dolomite aquifer. The groundwater resources of the watershed are relatively unspoiled and, if protected, can be relied upon as a continued source of water for domestic, commercial, and industrial uses.

About 80 percent of the watershed population receives Lake Michigan water through four public water utilities—the Milwaukee Water Works, the Wauwatosa Water Works, the West Allis Water Utility, and the Greendale Sewer and Water Utility. Inasmuch as the in-watershed portion of the Lake Michigan water supply system is not an integral part of the watershed hydrologic-hydraulic system, it is not considered further in the watershed study except as it might provide an alternative means of providing water to those areas of Ozaukee, Washington, and Waukesha County that are not adequately served by public water systems.

Six percent of the watershed population is served by the following four public utilities which rely on groundwater: the Germantown Water Utility, the Menomonee Falls Water Utility, the Butler Water Utility, and the Brookfield Water Utility. Inventories conducted under the watershed planning program indicate that none of these utilities is currently experiencing serious water quantity or quality problems nor does any of them expect such problems to develop in the immediate future. Before initiating major additions to their water supply systems, the groundwater utilities are considering the results of an engineering consultant's study that presents the results of an analysis of alternative intermunicipal water supply systems involving communities in and near the Menomonee River watershed. In light of the absence of serious existing or immediate future groundwater quality or quantity problems and the pending completion of the consultant's study, groundwater utilities are not considered further in the watershed planning process except as they might provide alternative means of giving water supply service to those contiguous urban areas not yet served by public water supply.

The remaining 14 percent of the watershed population—located primarily in the City of Brookfield, the Village of Menomonee Falls, the Village of Germantown, and the City of Mequon—is served by private groundwater supplies which generally use relatively shallow wells. About 88 percent of the area served by such systems also uses onsite waste disposal systems and is located on soils not suited for such systems. As a result, examples of aesthetic pollution have developed in recent years, bringing offensive odors and septic system discharges in low areas and drainage swales. An even more serious matter of concern is the health threat to area residents as a result of either direct contact with septic system discharge on the ground surface or as a result of the pollution of private groundwater supplies.

Certain commercial and industrial water users in the Menomonee River watershed are self-supplied in that they satisfy all or part of their water needs from private wells or by pumping directly from the streams. Various types of cooling processes account for most of this water use. Investigations carried out under the watershed study reveal that self-supplied industrial-commercial water users are not experiencing any serious quantity or quality problems nor is their pumping interfering with that of the four groundwater utilities. Because of the absence of problems and because of the reserve provided by the eight municipal water utilities in the watershed, self-supplied industrial and commercial water use is not explicitly addressed in the watershed plan.

Chapter VIII

WATER RESOURCE SIMULATION MODEL

INTRODUCTION

A quantitative analysis of watershed hydrology,[1] hydraulics,[2] and water quality under existing and alternative future conditions is a fundamental requirement of any comprehensive watershed planning effort. Of particular interest to the watershed planning process are those aspects of the hydrology and hydraulics of the watershed which affect peak flood discharges and stages and therefore flood control and floodland management planning and those aspects which affect water quality conditions, such as periods of critically low stream flows, and therefore water quality management planning. Discharge, stage, and water quality at any point and time within the surface water system[3] of a watershed are a function of three factors. The first is the meteorological events which determine the amount of runoff and, therefore, not only the amount of water that the stream system must carry in times of high flow, but also base flow levels and the amounts of water available for various in-stream uses including the maintenance of a fishery, recreation, and waste assimilation. The second factor is the nature and use of the land, with emphasis on those features that affect the quantity and temporal distribution of runoff and the quality of that runoff. The third factor is those stream characteristics that determine the manner in which runoff from the land moves through the stream system and, therefore, significantly influences flood discharges and stages, and the rate at which pollutants are either assimilated within or transported from the watershed.

Recently developed water resources engineering techniques make it possible to calculate existing and future hydrologic, hydraulic, and water quality conditions in a watershed as influenced by the above three factors. These techniques involve the formulation and application of mathematical models that simulate the behavior of the surface water system. These models, which are usually programmed for digital computer application, permit the necessary quantitative analysis of hydrology, hydraulics, and water quality under existing and alternative future conditions as required in the comprehensive watershed planning effort.

The purpose of this chapter is to describe the water resource model—actually a combined hydrologic, hydraulic, water quality, and flood economics model—used in the Menomonee River watershed planning program. More specifically, this chapter discusses the need for and nature of modeling in water resources planning, model selection, the submodels contained within the model, input data requirements and data base development, and model calibration. The voluminous quantity of input data used in the modeling effort is not included in this report but is available in Commission files.

WATER RESOURCES SIMULATION MODELING: BACKGROUND

Need for Modeling

The ideal way to investigate the behavior of the hydrologic-hydraulic-water quality system of a watershed would be to make direct measurements or observations of the phenomena involved. Such a direct approach is not generally feasible, however, primarily for three reasons. First, the costs are prohibitive for installing, operating, and maintaining the network of precipitation measurement gages, streamflow gages, water quality monitoring stations, and other monitoring equipment necessary to achieve the extensive, yet detailed, data required for watershed planning. Secondly, even if an ideal data collection system could be established in a watershed, it is highly improbable that the sampling or observation period available would include critical natural events such as the extreme low flow periods required for water quality planning purposes or the extreme high flow periods required for flood control and floodland management planning purposes. Finally, with respect to evaluating watershed hydrologic-hydraulic and water quality relationships under probable future land and stream conditions, it is apparent that a regional monitoring network would be of limited value since measurements and observations would only reflect existing conditions.

It follows, therefore, that achievement of the necessary detailed understanding of the spatial and temporal fluctuations in the quantity and quality of the surface water resources of a watershed under both existing and hypothetical watershed development conditions requires application of some planning technique which can supplement and build upon a necessarily limited base of empirical water resources data. The planning technique

[1] *Hydrology is the study of the physical behavior of water from its occurrence as precipitation to its entry into streams, lakes, or ponds to its return to the atmosphere via evapotranspiration.*

[2] *Hydraulics, as it relates to surface waters of a watershed, is the study of the physical behavior of water as it flows within stream channels and on natural floodplains, under and over bridges, culverts, and dams, and through lakes and other impoundments.*

[3] *A system is defined as a set of interdependent physical units and processes organized or arranged so as to interact in a predictable, regular manner, the understanding or manipulation of which can be used to advance some objective or function.*

must have the capability of quantifying the hydrologic-hydraulic-water quality-flood economics impact of existing and alternative future conditions with a degree of accuracy sufficient to permit sound decisions to be made concerning both the location, type, and size of costly water control structures and facilities and the nature and extent of water resource-related land management measures.

Hydrologic-hydraulic-water quality-flood economics simulation,[4] accomplished with a set of interrelated digital computer programs, has proven to be an effective water resources planning technique. Although systems may be simulated by means of programs executed on digital computers, by electric analogs, and by actual physical models, digital computer simulation has been utilized most extensively in water resources planning by private consulting firms and by governmental agencies, including the Commission, since the early 1960's, when private as well as public engineering and planning organizations began to gain access to digital computers and the mathematical programs required to apply the computers to water resources planning and engineering.

Nature of Modeling
A variety of digital computer models is available for use in water resources planning studies. These models range from a relatively simple set of mathematical expressions, or equations, that generate hydrographs for discrete hydrologic events to large and complex models that continuously simulate watershed hydrology, hydraulics, and water quality in response to changing meteorological conditions.

Discrete Event Versus Continuous Process Simulation: The difference between discrete event and continuous process simulation, particularly as related to hydrologic, hydraulic, and water quality modeling, is an important distinction since there is a marked difference in the capabilities and costs of these two fundamentally different approaches. Discrete event hydrologic-hydraulic models for example, are designed to simulate the response of a watershed or a portion of a watershed to a major rainfall or rainfall-snowmelt event by converting the rainfall or rainfall-snowmelt that occurs on the land into a hydrograph that can then be routed through the stream system. Such models are not intended for use in simulating the runoff attributable to small rainfall or rainfall-snowmelt events and do not simulate base flow conditions that occur in the streams before and after runoff events.

The principal advantages of discrete event hydrologic-hydraulic-water quality models relative to continuous process models is that they require relatively little meteorological data; and they can be operated on smaller computers with shorter run times. The principal disadvantages of discrete event models are that they require specification of design storm and antecedent moisture conditions, thereby assuming equivalance between the recurrence interval of a flood and the recurrence interval of the meteorological event that caused it; they cannot simulate minor flood or baseflow conditions; they cannot simulate long term transport of potential pollutants; and they are able to utilize only a small part of the available historic hydro-meteorologic and water quality data during calibration and testing.

Continuous process hydrologic-hydraulic models continously and sequentially simulate processes such as precipitation, interception and depression storage, snow accumulation and melt, evapotranspiration, direct runoff, infiltration and interflow, release from groundwater storage as base flow, and channel and reservoir routing. Such models typically operate on a time interval ranging from a day to a fraction of an hour and continuously maintain a water balance, or accounting, among the various hydrologic-hydraulic processes. The entire spectrum of streamflow conditions is simulated, ranging from flood flows occurring during and immediately after major runoff-producing events to extreme low flows typical of drought periods. Some continuous process models also continuously simulate water quality conditions that are associated with the hydrologic and hydraulic processes included in the model.

Continuous process models have two principal advantages relative to discrete event models. First, such models permit transformation of long, historic meteorological records—which are normally available and may extend over several decades—into a correspondingly long record of synthetic hydrologic, hydraulic, and water quality data encompassing thus a wide spectrum of possible occurrences. Statistical analysis of the simulated hydrologic, hydraulic, and water quality data series then permits conclusions to be drawn concerning the exceedance frequency of particular discharge, stage, or water quality levels. Second, continuous process models permit maximum utilization of most historic hydrologic, hydraulic, and water quality information, an important factor in the study of small urban watersheds that typically lack extensive data bases, therefore requiring maximum utilization of all the data that are available or are obtained specifically for a study. A principal disadvantage of continuous process models is that they require large amounts of input data—particularly daily and hourly meteorological information. Such voluminous data are often not available or, if available, require costly collation and coding. Another significant disadvantage of continuous process models is the extensive computer system storage and run time required with correspondingly high computer use costs.

With respect to the order of evolution, the development and use of discrete event models generally preceded that of continuous process models primarily because of the relative simplicity and more modest computer system requirements of the discrete event models. As a result, there are more discrete event models available and in use than continuous process models. A recent state-of-the-art

[4] *Simulation is defined as reproduction of the important behavioral aspects of a system. It should be emphasized that simulation, as used in comprehensive watershed planning, does not normally achieve, nor need to achieve, exact duplication of all aspects of system behavior.*

survey[5] of urban area models revealed the existence of 18 models that simulate the dynamics—time varying characteristics—of urban area hydrology, with some of the models also having the capability of simulating the dynamics of urban area hydraulics and water quality. Four of the 18 models were continuous simulation devices while the remaining 14 were discrete event models.

Algorithms: In order to simulate the hydrologic, hydraulic, and water quality system of a watershed by application of a digital computer, it is necessary to construct a mathematical algorithm of each system unit and concomitant processes and to then interconnect these algorithms so as to, in effect, represent the linked as well as the individual behavior of the system components. For example, most hydrologic-hydraulic models include determination of the storage effect of a stream reach on the shape of a hydrograph that passes through the reach. Simulation of this element of the system is accomplished by mathematically expressing the alteration in hydrograph shape as a function of reach geometry and hydraulic conditions. Similarily, the hydrograph that enters the reach is a function of all watershed hydrologic and hydraulic characteristics upstream of the reach.

It is important to emphasize that the model used in the Menomonee River watershed planning program, or more specifically the mathematical computations and logic decisions executed during the operation of that model, are no more and no less sophisticated or valid than the operations which could, with virtually unlimited personnel and time, be accomplished manually by technical personnel. The only advantage of digital computer simulation over manual computations is the rapidity of the computer computations and logic operations relative to the manual computations. The application of mathematical simulation models to water resources planning and engineering was dependent on the development of a computational device—the digital computer—capable of rapidly making, without error, voluminous repetitive calculations and logic operations and was not dependent on an increased understanding of hydrologic, hydraulic, and water quality processes. In fact, most of the hydrologic, hydraulic, and water quality phenomena included in the most sophisticated existing water resource simulation models were known and formulated many years prior to the advent of simulation, some as early as the eighteenth century. Because of the staff and time requirements and associated monetary costs, it would have been impractical to manually execute the computations necessitated in a single application of the model used in the Menomonee River watershed study.

SIMULATION MODEL USED IN THE MENOMONEE RIVER WATERSHED PLANNING PROGRAM

Model Selection Criteria

Prior to selection of a hydrologic-hydraulic-water quality-flood economics model for use in the Menomonee River watershed planning program, the proposed planning program as well as the water resource problems of the watershed were examined in order to determine the applicability of simulation modeling. Based on that examination, it was determined that the "ideal" model should have the following capabilities or features:

1. Be able to simulate the hydrology, hydraulics, and water quality conditions of streams and watercourses in both rural and urban areas.

2. Be able to compute 100-year recurrence interval flood discharges and stages with sufficient accuracy for use in delineating floodland regulatory districts and areas.

3. Be able to calculate a wide range of flood discharges and stages for federal flood insurance study purposes.

4. Be able to accurately incorporate the effects of hydraulic structures such as bridges, culverts, and dams and of localized floodland encroachments on upstream and downstream flood discharges and stages.

5. Be able to compute average annual flood damages and benefits attendant to various flood discharges and stages.

6. Be able to accurately incorporate the hydrologic and hydraulic effects of land use changes—particularly the effects of the conversion of land from rural to urban uses—not only within the floodlands but within the entire tributary watershed.

7. Be able to accurately incorporate the hydrologic and hydraulic effects of alternative structural flood control works such as channelization, dikes and floodwalls, and storage impoundments.

8. Permit assessment of the impact on surface water quality of discharges from point sources of pollution such as municipal and industrial discharges.

9. Permit assessment of the impact on surface water quality of diffuse sources of pollution, such as organic materials and plant nutrients washed from the land surface or leached out of soil profiles.

In addition to these nine criteria which pertain directly to the needs of the Menomonee River watershed planning program, the model selection process also included consideration of two additional factors related to the overall work program of the Commission. First, inasmuch as the installation of a new model, or a portion of a new model, requires considerable staff time and expense, maximum use should be made of existing in-house models. Second, the model selected for use in the Menomonee River watershed planning program should have the potential to substantially fill the water resource simulation modeling needs of other ongoing or scheduled Commission water resources planning programs. During that time period in

[5] *A. Brandstetter, "Comparative Analysis of Urban Stormwater Models," Battelle Memorial Institute, Richland, Washington, August 1974, 88 pp.*

which the model was being selected and implemented on the Commission's computer system—approximately June 1974 to April 1975—the Commission was either participating in or planning to undertake the following major water resource related studies: the International Joint Commission Menomonee River Pilot Watershed Study,[6] the Kinnickinnic River watershed planning program,[7] and the areawide water quality planning and management program.[8] Since it was anticipated that the model or portions of it would be extensively used in these and other Commission water resources planning programs over a period of several years, it was deemed desirable to select a flexible model and one for which some formal model maintenance, refinement, and extension services were available.

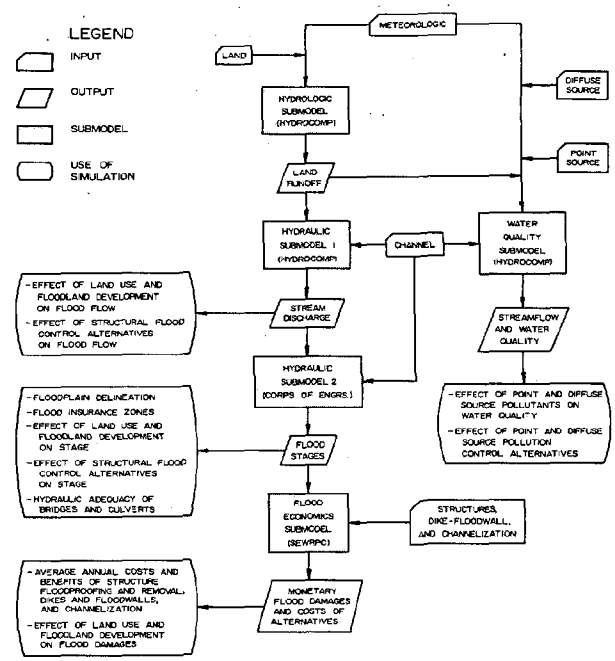
Model Selection

No single digital computer model existed that had the capability of meeting all of the selection criteria. Therefore, the modeling requirements were satisfied by using a combination of several different existing digital computer programs—a model "package"—that could be used in sequence to satisfy the modeling needs of the Commission water resource-related planning programs, underlying the Menomonee River watershed planning program. Figure 64, which graphically illustrates the overall structure of the selected model, identifies five submodels, or computer programs, within the model that perform the calculations; shows the relationships between these submodels; indicates the input and output of each submodel; and indicates the uses of the simulation model application results. The set of submodels contains both continuous process and discrete event submodels selected so as to maximize the favorable features of each of the two basic model types.

The Hydrologic Submodel, Hydraulic Submodel 1, and the Water Quality Submodel are three computer programs contained within a program package called "Hydrocomp Simulation Programming."[9,10] This computer program,

Figure 64

HYDROLOGIC-HYDRAULIC-WATER QUALITY-FLOOD ECONOMICS MODEL USED IN THE MENOMONEE RIVER WATERSHED PLANNING PROGRAM



Source: SEWRPC.

which is available on a proprietary basis through the consulting firm Hydrocomp, Inc., has been under development since the early 1960's when pioneer work in hydrologic-hydraulic modeling was initiated at Stanford University.[11] In 1972, the Hydrocomp firm added a water quality simulation capability to the hydrologic-hydraulic simulation capability of the model. The Hydrocomp programming, that is, the Hydrologic Submodel, Hydraulic Submodel 1, and the Water Quality Submodel are continuous process submodels that are installed on the SEWRPC computer system in late 1974 and early 1975.

The submodel identified as Hydraulic Submodel 2, is the U. S. Army Corps of Engineers program called "Water Surface Profiles."[12] This discrete event, steady state model was provided to the Commission without cost by the Hydrologic Engineering Center of the Corps of Engineers

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[6] *Wisconsin Department of Natural Resources, University of Wisconsin System—Water Resources Center, and Southeastern Wisconsin Regional Planning Commission, Menomonee River Pilot Watershed Study Work Plan, September 1974, 44 pp.*

[7] *Southeastern Wisconsin Regional Planning Commission, Kinnickinnic River Watershed Planning Program Prospectus, November 1974.*

[8] *Southeastern Wisconsin Regional Planning Commission, Study Design for the Areawide Water Quality Planning and Management Program for Southeastern Wisconsin, 1975-1977, Revised August 1975, 181 pp.*

[9] *Hydrocomp, Inc., Hydrocomp Simulation Programming Operations Manual, Fourth Edition, January 1976.*

[10] *Hydrocomp, Inc., Hydrocomp Simulation Programming—Mathematical Model of Water Quality Indices in Rivers and Impoundments, 1972.*

[11] *N. H. Crawford and R. K. Linsley, Digital Simulation in Hydrology: Stanford Watershed Model IV, Technical Report No. 39, Department of Civil Engineering, Stanford University, July 1966.*

[12] *U. S. Army Corps of Engineers, Hydrologic Engineering Center, Computer Program 723-X6-L202A, HEC-2, Water Surface Profiles Users Manual, Davis, California, October 1973.*

and is continuously maintained by the Center at no cost to the Commission. This large computer program has been used extensively by the Commission in its floodland management planning and plan implementation activities since mid-1972,[13] and has been operable on the Commission computer system since February 1974.

The Flood Economics Submodel is an extension of a computer program originally prepared by the Commission staff in November 1973 for the purpose of conducting an economic analysis of floodland management alternatives along the North Branch of the Root River in the City of West Allis. Documentation for the Flood Economics Submodel, a discrete event model, is available at the Commission offices.

Each of the five submodels is discussed below. These separate discussions emphasize the function of each submodel within the overall modeling scheme, the types of algorithms that are contained within each submodel, data needs, and the kinds of output that are provided. The reader is referred to the above referenced reports and manuals for detailed descriptions of each submodel.

Hydrologic Submodel

The principal function of the Hydrologic Submodel is to determine the volume and temporal distribution of flow from the land to the stream system. As used here, the concept of runoff from the land is broadly interpreted to include direct or surface runoff, interflow, and groundwater flow to the streams. The amount and rate of runoff from the land to the watershed stream system is largely a function of two factors. The first is the meteorological events which determine the quantity of water available on or beneath the land surface and the second key factor is the nature and use of the land.

The basic physical unit on which the Hydrologic Submodel operates is called the "hydrologic land segment." A hydrologic land segment is defined as a surface drainage unit that exhibits a unique combination of meteorological parameters, such as precipitation and temperature, and land characteristics, such as proportion covered by impervious surfaces, soil type, and slope. A strict interpretation of this definition would lead to the conclusion that there is virtually an infinite number of hydrologic land segments within even a small watershed because of the large number of meteorological parameters and land characteristics and because each such parameter exhibits a continuous, as opposed to discrete, spatial variation throughout the watershed.

A practical, operational definition of a hydrologic land segment is a surface drainage unit consisting of a subbasin, or a combination of subbasins, within the geographic area which can be considered represented by a particular meteorological station and which is relatively uniform with respect to three land characteristics: soil type, slope, and land use or cover. For purposes of identifying the hydrologic land segment types comprising a watershed, a Thiessen polygon network was first constructed to determine the geographical area to be represented by each meteorological station in the watershed or adjacent thereto. Soil type as represented by one of two hydrologic soil groupings, land use and cover as classified into one of five categories, and slope as defined in terms of one of two ranges were then superimposed on the Thiessen polygon, and the resulting hydrologic land segment types and land segments were identified and mapped. As described later in this chapter, 16 hydrologic land segment types and 108 hydrologic land segments were identified within the Menomonee River watershed for the modeling of existing conditions.

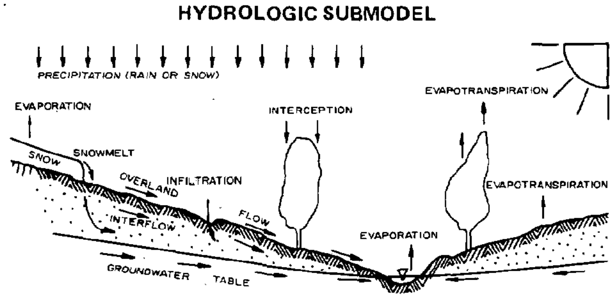
The hydrologic processes explicitly simulated within the Hydrologic Submodel are shown in Figure 65. The submodel, operating on a time interval of one hour or less, continuously and sequentially maintains a water balance within and between the various hydrologic processes. The water balance accounting procedure is based on the interdependence between the various hydrologic processes shown schematically in Figure 66. The Hydrologic Submodel maintains a running account of the quantity of water that enters, leaves, and remains within each phase of the hydrologic cycle during each successive time interval.

As already noted, the volume and rate of runoff from the land is determined by meteorological phenomena and the nature and use of the land. Therefore, meteorological data and land data constitute the two principal types of input data for each land segment type in the Hydrologic Submodel. Table 69 identifies the seven categories of historic meteorological data sets that are input directly or indirectly to the Hydrologic Submodel for each land segment type and notes the use of each data set. The procedures used to acquire and code the seven different types of meteorological data sets used in simulating the hydrologic response of the Menomonee River watershed land surface are described later in this chapter.

Table 70 identifies the 28 land or land-related parameters that are input to the Hydrologic Submodel for each hydrologic land segment type and indicates the primary

Figure 65

PROCESSES SIMULATED IN THE HYDROLOGIC SUBMODEL

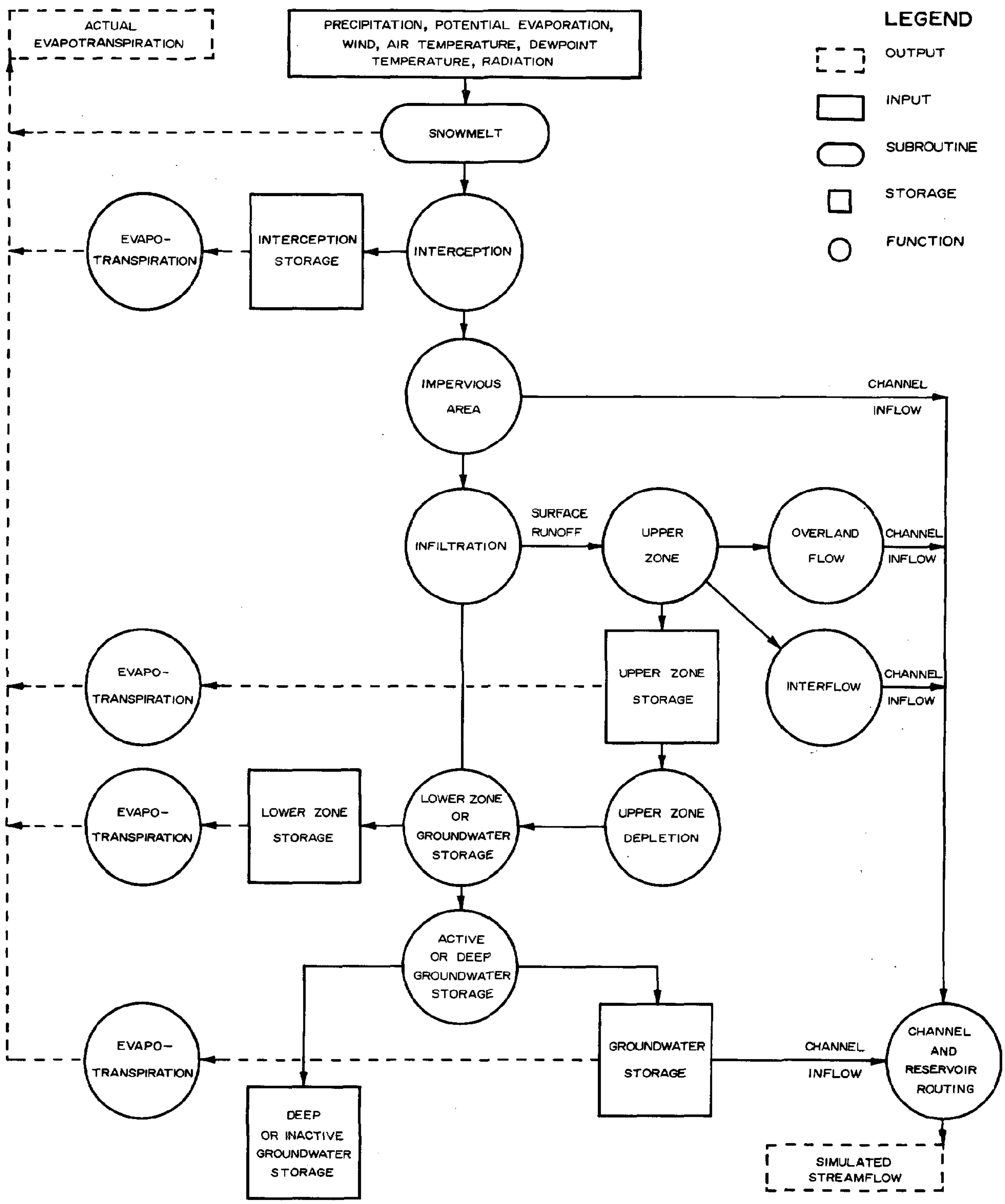


Source: Hydrocomp, Inc., and SEWRPC.

[13] From late 1970 to mid-1972, the Commission used the U. S. Army Corps of Engineers program "Backwater—Any Cross-Section," the predecessor of the current program.

Figure 66

INTERDEPENDENCE BETWEEN PROCESSES IN THE HYDROLOGIC SUBMODEL



Source: Hydrocomp, Inc., and SEWRPC.

Table 69

METEOROLOGICAL DATA SETS AND THEIR USE IN THE HYDROLOGIC AND WATER QUALITY SUBMODELS APPLIED IN THE MENOMONEE RIVER WATERSHED PLANNING PROGRAM

Data Set	Units	Frequency		Origin of Data		Use in Hydrologic Submodel	Use in Water Quality Submodel	Use in Synthesizing Other Meteorological Input Data for the Submodels
		Desirable	Allowable	Historic	Computed			
Precipitation	10^{-2} inches	Hourly or more frequent	Daily	X	--	Rain or snowfall applied to the land Data from hourly stations used to disaggregate data from daily stations	--	--
Radiation	Langleys/ Day[a]	Daily	Semimonthly	--	X	Snowmelt	Water temperature-heat flux to water by short wave solar radiation	Compute potential evaporation
Potential Evaporation	10^{-3} inches	Daily	Semimonthly	--	X	Evaporation from lakes, reservoirs, wetlands, depression storage, and interception storage Evapo-transpiration from upper zone storage, lower zone storage, and groundwater storage Evaporation from snow	--	--
Temperature	^{o}F	Daily (maximum and minimum)	--	X	--	Snowmelt Density of new snow Occurrence of precipitation as snow	Water temperature-heat flux to water surface by long wave solar radiation Water temperature-Heat flux from water by conduction-convection	Average daily temperature used to compute evaporation
Wind Movement	Miles/Day	Daily	--	X	--	Snowmelt by condensation-convection Evaporation from snow	Water temperature-heat loss from water surface by evaporation Lake reaeration	Compute evaporation
Dewpoint-Temperature[b]	^{o}F	Daily	Semimonthly	X	--	Snowmelt by condensation-convection Evaporation from snow	Water temperature-heat loss from water surface by evaporation	Compute evaporation
Cloud Cover	Decimal fraction	Daily	Semimonthly	X	--	--	Water temperature-heat flux to water surface by long wave solar radiation.	--
Sunshine	Percent possible	Daily	--	X	--	--	--	Compute solar radiation which was in turn used to compute evaporation.

[a] Solar energy flux, that is, the rate at which solar energy is delivered to a surface—such as the earth's surface—is expressed in terms of energy per unit area per unit time. The langley expresses energy per unit area and is equivalent to 1.0 calories/cm^2 or 3.97 x 10^{-3} BTU/cm^2. Therefore, a langley/day, which expresses solar energy flux in terms of energy per unit area per unit time, is equivalent to 1.0 calories/cm^2/day or 3.97 x 10^{-3} BTU/cm^2/day. The solar energy flux above the earth's atmosphere and normal to the radiation path is about 2,880 langleys/day.

[b] Dewpoint temperature is the temperature at which air becomes saturated when cooled under conditions of constant pressure and constant water vapor content.

Source: Hydrocomp, Inc., and SEWRPC.

Table 70

PARAMETERS REQUIRED FOR EACH HYDROLOGIC LAND SEGMENT SIMULATED WITH THE HYDROLOGIC SUBMODEL

Parameter Number	Parameter Symbol	Definition or Meaning	Unit	Primary Source of Numerical Value[a]
1	K1	Ratio of average annual segment precipitation to average annual precipitation at measuring station	None	Isohyetal map of annual precipitation
2	A	Impervious area factor related to directly connected impervious area in segment as a percent of total area	None	Aerial photographs
3	EPXM	Maximum interception storage	Inches	Extent and type of vegetation as determined from aerial photographs and field examination
4	UZSN	Nominal transient groundwater storage in the upper soil zones	Inches	A function of LZSN and therefore determined primarily by calibration
5	LZSN	Nominal transient groundwater storage in the lower soil zones	Inches	Related to annual precipitation but determined primarily by calibration
6	K3	Evaporation loss index: percent of segment area covered by deep-rooted vegetation	None	Extent and type of vegetation as determined from aerial photographs and field examination
7	K24L	Decimal fraction of the groundwater recharge that percolates to deep or inactive groundwater storage	None	--[b]
8	K24EL	Decimal fraction of land segment with shallow groundwater subject to direct evapotranspiration	None	Soils and topographic data
9	INFILTRATION	Nominal infiltration rate	None	Calibration
10	INTERFLOW	Index of Interflow	None	Calibration
11	L	Average length of overland flow	Feet	Topographic maps
12	SS	Average slope of overland flow	None	Topographic maps
13	NN	Manning roughness coefficient for overland flow	None	Field reconnaissance
14	IRC	Interflow recession rate	None	Hydrograph analysis
15	KK24	Groundwater recession rate	None	Hydrograph analysis
16	KV	Variable to permit the KK24 to vary with the groundwater slope	None	--[b]
17	RADCON	Adjust theoretical snowmelt equations to field conditions	None	--[b]
18	CONDS-CONV	Adjust theoretical snowmelt equations to field conditions	None	--[b]
19	SCF	Adjust snowfall measurements to account for typical catch deficiency	None	--[c]
20	ELDIF	Elevation of segment above mean elevation of temperature station	10^3 feet	Topographic maps
21	IDNS	Density of new snow at $0^{o}F$	None	--[b]
22	F	Decimal fraction of land segment with forest cover	None	Aerial photographs
23	DGM	Groundmelt rate attributable to conduction of heat from underlying soil to snow	Inches/day	--[b]
24	WC	Maximum water content of the snowpack, expressed as a fraction of the water equivalent of the pack, that is, the maximum amount of liquid water that can be accumulated in the snowpack	None	--[c]
25	MPACK	Water equivalent of snowpack when segment is completely covered by snow	Inches	--[b]
26	EVAPSNOW	Adjust theoretical snow evaporation equations to field conditions	None	--[b]
27	MELEV	Mean elevation of segment	Feet Sea Level Datum	Topographic map
28	TSNOW	Air temperature below which precipitation occurs as snow	^{o}F	--[b]

[a] *Regardless of the primary source of parameter values, all land parameters were subject to adjustment during the calibration process.*

[b] *Initial values were assigned based on experience with the Hydrologic Submodel on watersheds having similar geographic or climatological characteristics. For example, refer to "Simulation of Discharge and Stage Frequency for Flood Plain Mapping in the North Branch of the Chicago River" by Hydrocomp, Inc., for the Northeastern Illinois Planning Commission, February 1971, 75 pp.*

[c] *Initial values were assigned based on information and data reported in hydrology textbooks. For example, refer to R. K. Linsley, M. A. Kohler, and J. L. H. Paulhus, Hydrology for Engineers, Second Edition, McGraw-Hill, N. Y. 1975.*

Source: Hydrocomp, Inc., and SEWRPC.

source of numerical values for each parameter. Numerical values assigned to each of these land parameters for a given land segment have the effect of adapting the Hydrologic Submodel to the land segment type. The procedures used to assign values to the land parameters for each hydrologic land segment type are described later in this chapter.

Hydraulic Submodel 1

The primary function of Hydraulic Submodel 1 is to accept as input the runoff from the land surface and the discharge of groundwater as produced by the Hydrologic Submodel, aggregate it in, and route[14] it through the stream system, thereby producing a continuous series of discharge values at predetermined locations along the rivers and streams of the watershed. Computations proceed at a time interval of an hour or fraction thereof and statistical analyses performed on resulting continuous series of discharges yield the discharge-frequency information that is then input to Hydraulic Submodel 2 for calculation of stage. Stages are also computed by Hydraulic Submodel 1 but, because of the highly simplified manner in which channel-floodplain geometry is represented in the model, these stages are not, in the opinion of the Commission staff, accurate enough for certain watershed planning purposes, including mapping of floodland regulatory zones, testing the hydraulic adequacy of bridges and culverts, and determination of flood damages. The discharges produced by Hydraulic Submodel 1 are, however, judged adequate for all watershed planning applications.

In addition to maintaining a continuous accounting of inflow to the stream system, Hydraulic Submodel 1 performs two types of routing calculations—one for channel reaches and another for impoundments, that is, lakes and reservoirs. These two routing procedures are similar in concept in that both employ the conservation of mass principle and basic hydraulic laws. The procedures differ significantly, however, with respect to input data needs and the detailed manner in which the computations are executed. For the purpose of applying these two routing techniques the channel system is divided into reaches and impoundment sites.

Reach routing is accomplished on a continuous basis using the kinematic wave technique. Application of this technique requires that the following information be provided for each reach: length; upstream and downstream channel invert elevation; a channel-floodplain cross-section consistent with a prismatic representation of the reach; Manning roughness coefficients for the channel and the floodplains; and size and other characteristics of the tributary drainage area.

[14] *Routing refers to the process whereby a streamflow hydrograph for a point at the entrance to a river reach or an impoundment such as a lake or reservoir is significantly attenuated—that is, the peak flow is reduced and the base lengthened—through the reach or impoundment as a result of either temporary channel-floodplain storage or temporary impoundment storage.*

Table 71 identifies the 15 channel-related parameters that are input to Hydraulic Submodel 1 for each reach and indicates the primary source of numerical values for each. Numerical values assigned to each of these channel parameters for a given reach have the effect of adapting Hydraulic Submodel 1 to the reach. The principal means of establishing the channel parameters is direct observation or measurement of the watershed stream system. Additional information on the procedures used to assign values to the channel parameters for each channel reach is presented later in this chapter.

As simulated by the kinematic wave routing algorithm, a volume of flow enters the reach during a given time increment with the flow entering from the reach immediately upstream or coming directly from the land contiguous to the reach. The incremental volume of flow is added to that already in the reach at the beginning of the time interval, and the Manning equation is then used to estimate the discharge rate within the reach during the time increment and, thereby, the volume of flow that would discharge from the reach during the time increment. The volume of water in the reach at the end of the time increment is then calculated as the initial volume plus the inflow volume minus the outflow volume. The above computational process is then repeated for the next time increment and, as in the case for the first time increment, the average flow rate from the reach is obtained. The channel routing computations proceed in a similar manner for subsequent time increments in the reach in question and for all other reaches, thus effectively simulating the passage of flood waves through the channel system.

Impoundment routing through lakes or reservoirs is accomplished on a continuous basis using the technique known as reservoir routing. Use of this analytic procedure requires that a stage-discharge-cumulative storage table be prepared for each reservoir with the values selected so as to encompass the entire range of physically possible reservoir water surface elevations. As simulated by the reservoir routing algorithm, a volume of flow enters the impoundment during a particular time increment with the origin of the flow being discharge from a reach or impoundment immediately upstream and from land contiguous to the impoundment. The incremental volume of flow is added to that already in the impoundment at the beginning of the time interval, and the stage-discharge-cumulative volume relationship is then used to estimate the rate of discharge from the impoundment during the time increment. The volume of water stored in the impoundment at the end of the time increment is calculated as the initial volume plus the inflow volume minus the outflow volume. This computational process is then repeated for subsequent time increments with the result of each such computation being the stage of, and the discharge rate from, the impoundment at the end of each time increment. Any number of stage-discharge-storage relationships may be utilized for a given existing or potential lake or reservoir site thus facilitating the simulation of a variety of potential outlet works and operating procedures.

Table 71

CHANNEL PARAMETERS REQUIRED FOR EACH REACH SIMULATED WITH HYDRAULIC SUBMODEL 1

DISCHARGE-RELATED PARAMETERS

Parameter				
Number	Symbol	Definition of Meaning	Unit	Primary Source of Numerical Value
1	REACH	Reach identification number	None	Assigned so as to increase in the downstream direction
2	LIKE	Permits repeating W1, W2, H, S-FP, N-CH, and N-FP of a preceding reach by entering the number of that reach	None	--
3	TYPE[a]	Indicates the type of channel or the presence of an impoundment. RECT indicates a rectangular channel, CIRC indicates a circular conduit and DAM indicates the presence of a dam and an impoundment	None	Observed condition of existing stream system or hypothetical future condition of stream system
4	TRIB	Identification number of the reach that the reach in question is tributary to	None	Stream system configuration and assigned identification numbers
5	SEGMT	Index number of land segment type tributary to reach	None	Map of watershed subbasins and stream system
6	TRIB-AREA	Watershed area directly tributary to reach	Square Miles	

CROSS SECTION-RELATED PARAMETERS

Parameter				
Number	Symbol	Definition of Meaning	Unit	Primary Source of Numerical Value
7	LENGTH	Length of reach	Miles	Map of watershed subbasins and stream system
8	EL-UP	Channel bottom elevation at upstream end of reach	Feet	Channel bottom profile
9	EL-DOWN	Channel bottom elevation at downstream end of reach	Feet	
10	W1	Channel bottom width	Feet	Generalized, representative reach floodland cross-section-constructed from detailed cross-sections prepared for Hydraulic Submodel 2
11	W2	Channel bank-to-bank width	Feet	
12	H	Channel depth	Feet	
13	S-FP	Lateral slope of the floodplains	None	

ROUGHNESS COEFFICIENTS

Parameter				
Number	Symbol	Definition of Meaning	Unit	Primary Source of Numerical Value
14	N-CH	Manning roughness coefficient for the channel	None	Coefficients established for Hydraulic Submodel 2 revised as needed during calibration
15	N-FP	Manning roughness coefficient for both floodplains	None	

[a] *If TYPE is CIRC, then W1 is replaced with DIA—circular conduit diameter in inches—and W2 is replaced by NN-CH—Manning roughness coefficient for the conduit—and the following channel parameters are not needed: H, S-FP, N-CH, N-FP.*
If TYPE is DAM, then the channel parameters are replaced with a set of parameters describing the dam and its impoundment.

Source: Hydrocomp, Inc. and SEWRPC.

Hydraulic Submodel 2

The primary function of Hydraulic Submodel 2 is to determine the flood stages attendant to the flood flows of specified recurrence interval produced by Hydraulic Submodel 1. Given a starting discharge and stage, this "backwater" computer program employs the principles of conservation of mass and energy to calculate river stages at successive, preselected upstream locations.

A computational procedure known as the "standard step method" is used in floodland reaches between hydraulic structures such as bridges, culverts, and dams. Given a discharge and stage at a starting floodland cross-section, a trial stage is selected for the next upstream cross-section. The Manning equation for open channel flow is used to calculate the mechanical energy loss between the two cross-sections, and then a check is made to determine if the conservation of energy principle is satisfied. If not, another upstream stage is selected and tested, and the process repeated until the unique upstream stage is found at which the conservation of energy is satisfied. The above iterative computational process is then repeated for successive upstream floodland reaches. The end result is a calculated flood stage at each of the cross-section locations.

Hydraulic Submodel 2 also determines the hydraulic effect of a bridge or culvert and the associated approach roadways by computing the upstream stage as a function of the downstream stage, flood discharge, and the physical characteristics of the hydraulic structure. Starting downstream of the structure, the mechanical energy loss due to the expansion of the flow leaving the structure is computed, then the energy losses directly attributable to flow through or over the structure are calculated, and finally the energy loss due to contraction of the flow approaching and entering the structure is computed. Flow through or over a bridge or culvert may consist of various combinations of open channel flow, pressure flow, and weir flow depending on the position of the upstream stage relative to the low chord of the waterway opening and the profile of the roadway surface.

Input data for that portion of Hydraulic Submodel 2 that performs backwater computations through floodland reaches between hydraulic structures include flood discharges, channel-floodplain cross-sections including distances between such sections, and Manning roughness coefficients for the channel and each floodplain. Data requirements for that portion of Hydraulic Submodel 2 that calculates the hydraulic effect of bridges, culverts, and other hydraulic structures include: channel bottom elevations, waterway opening measurements, pier position and shape, profiles along the approach roads and across the structure from one side of the floodland to the other, and dam crest shape and elevation.

The backwater computations assume proper waterway opening design and maintenance so that the full waterway opening of each bridge or culvert, as it existed at the time of the hydraulic structure inventory, is available for the conveyance of flood flow. In recognition of the fact that waterway openings can be temporarily blocked as a result of ice and buoyant debris being carried on floodwaters, floodplain regulations applicable to areas adjacent to or on the fringes of flood-prone areas normally require protection to an elevation equal to the 100-year recurrence interval flood stage plus a freeboard of 2.0 feet. A similar freeboard is normally used in the design of structural flood control works intended to convey 100-year flood flows such as dikes and floodwalls or major channel modifications.

Flood Economics Submodel

The Flood Economics Submodel fulfills two principal functions in the total simulation modeling. The first function is to calculate flood stage-damage relationships for urban riverine areas under a variety of developmental conditions which can then be used to estimate average annual monetary damages. The second key function of the Flood Economics Submodel is to calculate the cost of alternative flood control and floodland management measures, including the cost of floodproofing and of removal of flood-prone structures, the cost of alternative configurations of earthen dikes and concrete floodwalls, and the cost of major channel modifications. Capital costs as well as operation and maintenance costs are calculated by the submodel and the total costs are summarized on both a present worth and average annual basis.

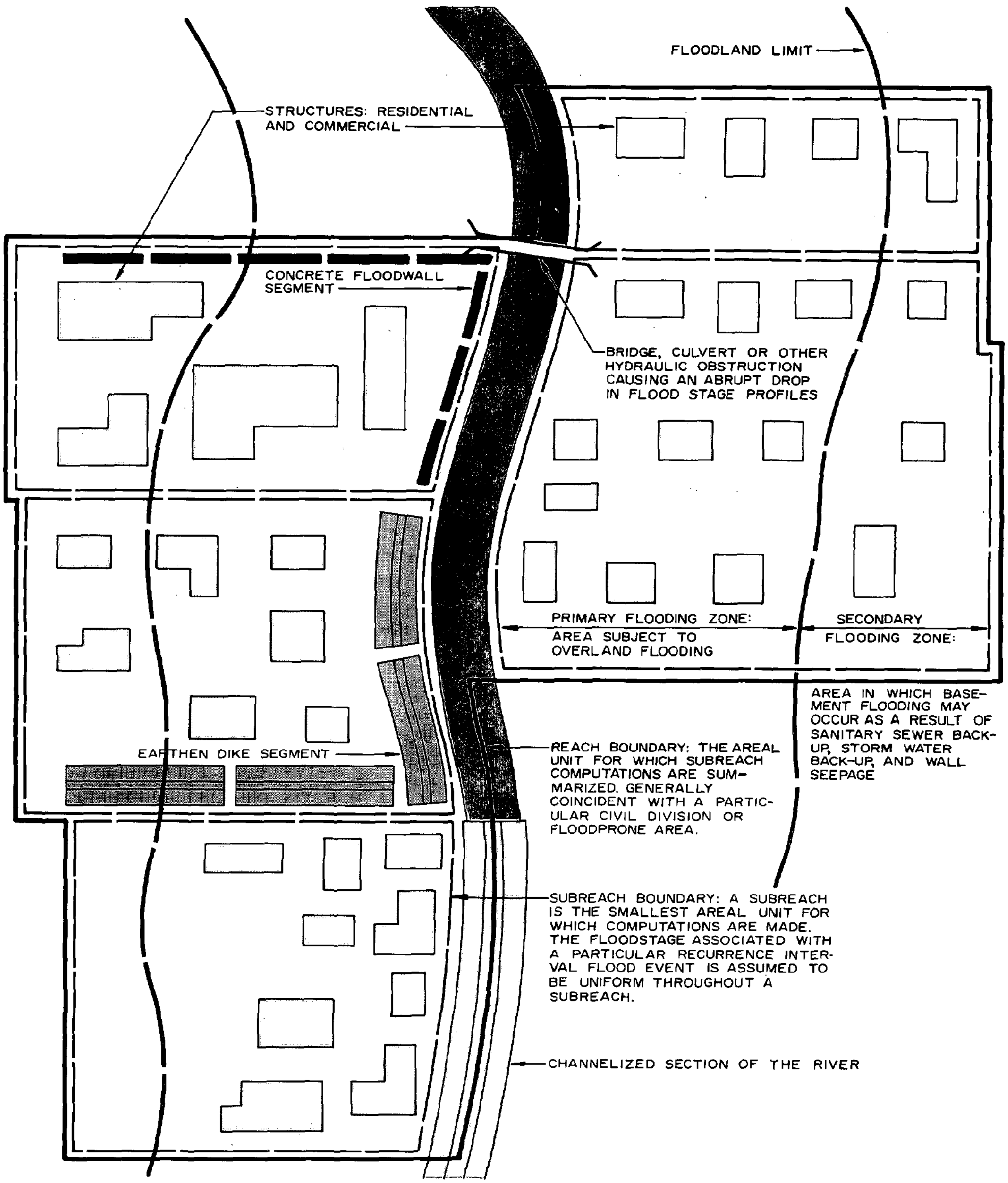
Figure 67 depicts a typical urbanized floodland area as represented in the Flood Economics Submodel. The subreach is the smallest areal unit for which computations of flood damage, floodproofing and removal costs, dike-floodwall, and channel modification costs are made. The principal consideration in selecting the limits of a subreach is that flood stages be approximately uniform throughout the subreach. The largest areal unit for which damages and costs are calculated by the submodel is the reach, the limits of which are normally selected so that the reach is encompassed entirely with a given civil division or encompasses a particular flood-prone area within a civil division.

The submodel contains stage-damage relationships for residential and commercial buildings. Structure stage-damage relationships were obtained from the Federal Insurance Administration and modified by SEWRPC. Indirect damages for industrial-commercial structures were computed within the Flood Economics Submodel as 40 percent of direct damages while 15 percent was used for residential structures. Stage-damage relationships are used in the submodel to calculate the flood damage within a subreach for each specified flood stage. By inputing a series of flood stages, a subreach stage-damage relationship is computed which, when combined with a stage-probability relationship obtained from Hydraulic Submodel 2, yields an estimate of average annual flood damage for the subreach.[15] A discussion of stage-damage

[15] *The per event and average annual flood damages are accurate for planning and analysis purposes on a subreach basis inasmuch as average stage-damage relationships for various types of structures are used in the submodel and inasmuch as average stages for various recurrence intervals are assigned to each subreach. Although submodel computational procedures include the calculation of flood damages to each structure within the subreach as part of the sequential process of obtaining flood damages for all structures in the subreach, the model is not intended, because of the "average" nature of the input, for computation of per event or average annual flood damages on a structure-by-structure basis.*

Figure 67

TYPICAL URBANIZED FLOODLAND AS REPRESENTED IN THE FLOOD ECONOMICS SUBMODEL



Source: SEWRPC.

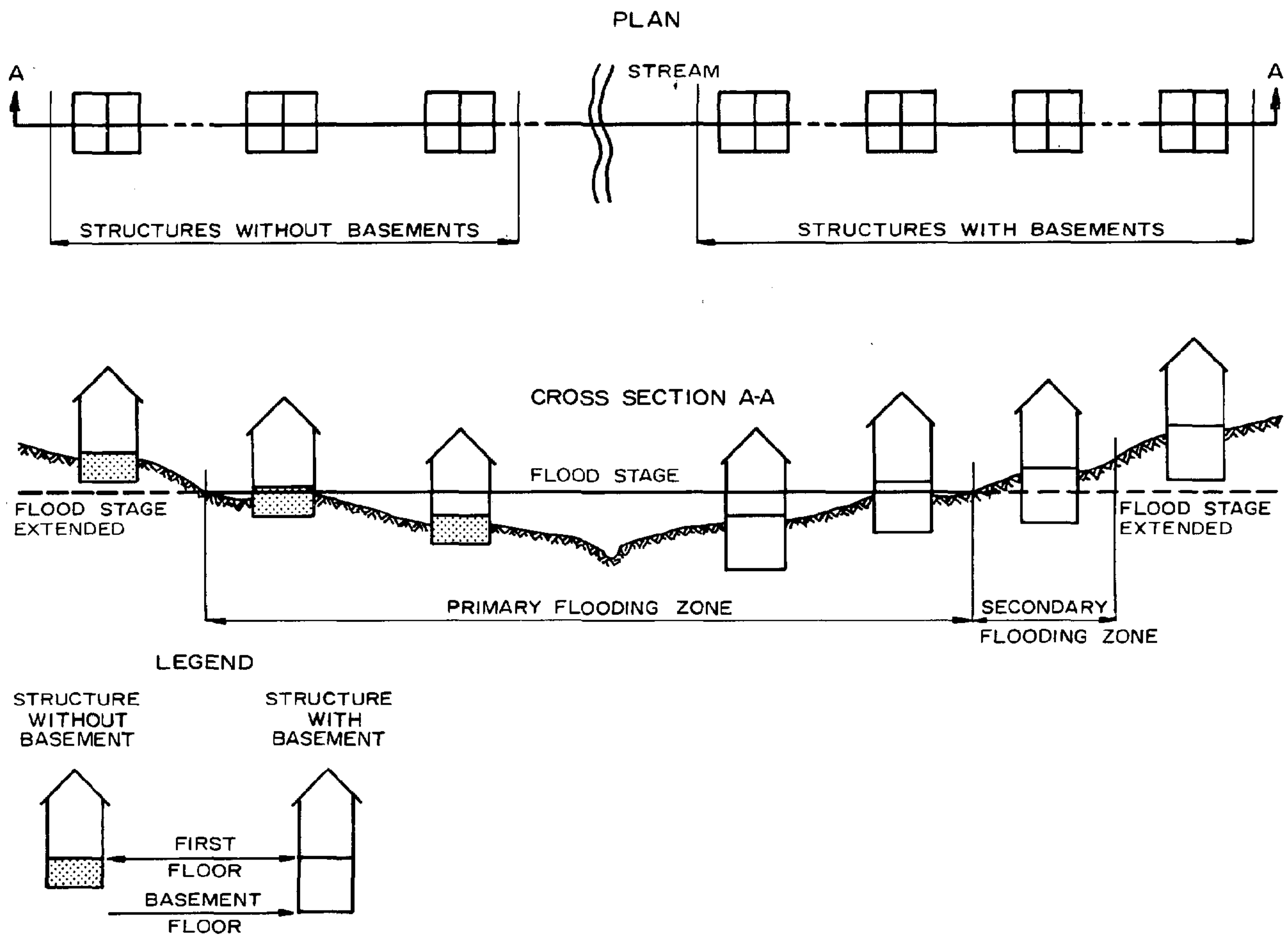
and stage-probability relations and the methodology used to determine average annual flood risks from such relationships are included in Chapter VI of this volume. Standard structure stage-damage relationships as used within the Flood Economics Submodel also are presented in that chapter.

As discussed in Chapter VI of this volume, the flood-prone area along a stream may usually be subdivided into two zones: a primary or overland flooding zone in which both basement and first floor damage may occur, and a secondary flooding zone located adjacent to the primary flooding zone in which basement damage may occur as a result of the hydraulic connections—such as sanitary and combined sewers or saturated soil conditions—between the primary zone and the basements in the secondary zone. Figure 68 illustrates the manner in which primary and secondary flooding are reflected in the Flood Economics Submodel. Within the primary flooding zone, structures with basements are assumed to incur the full potential basement damage corresponding to the flood stage while structures with or without basements are assumed to incur first floor damage if the flood stage is at or above first floor elevation.

First floor damage is not possible in the secondary flooding zone, and basement damage is assumed to occur only if the flood stage is at or above the basement elevation of structures having basements. In recognition of the fact—based on the historic flood surveys—that not all structures with basements in the secondary flooding zone do actually incur basement flooding, basement flood damages are assumed to be a fraction of the full potential basement damage. The fraction assigned to a given reach is a function of several factors, the first of which is historic evidence of secondary flooding with emphasis on the percent of structures in the secondary flood area that actually experienced basement damage. Another factor considered in establishing the secondary flooding fraction is the presence of a sanitary or combined sewer system

Figure 68

FLOOD DAMAGE COMPUTATION LOGIC FOR PRIMARY AND SECONDARY FLOOD ZONES



Source: SEWRPC.

or saturated soil conditions since such systems and conditions provide a mechanism for the occurrence of secondary flooding. A third factor to consider in evaluating the likelihood of secondary flooding is the existence of storm sewer system segments that may work in reverse during a flood event and convey floodwater from the stream to scattered low areas located some distance from the stream. The fourth factor to consider in evaluating the likely intensity of secondary flooding applies to channelized reaches. Secondary flooding is usually a relatively minor problem in riverine areas adjacent to channelized reaches because the channels are designed to carry floodflows at relatively low stages and because the design of such structures normally includes examination of and elimination of potential hydraulic connections between flood flow in the channelized reach and adjacent sanitary, storm and combined sewer systems. If, however, the channelized reach does not have the capacity to contain major flood flows, then the potential for secondary flooding is high inasmuch as the resulting overland flooding is likely to surcharge the sewer systems in large areas of the typically flat adjacent lands resulting in sewer backup into basements.

The cost of floodproofing an individual structure is represented in the submodel as a function of the nature and value of the structure and the level of protection relative to the first floor subject to a maximum stage above which floodproofing is not considered feasible. The inclusion of this function facilitates calculation of the total cost of floodproofing the structures within a subreach for a specified flood stage.

The cost of removing a structure from a flood-prone area is computed as the sum of structure acquisition cost, structure demolition or moving costs, occupant relocation costs, and site restoration costs. A structure is considered for removal when the design flood stage exceeds the elevation above which floodproofing is not feasible. Inclusion of the structure-removal algorithm permits computation of the total cost of structure floodproofing and removal within a subreach for a specified flood stage. Comparison of floodproofing and removal costs to the average annual damages that would be alleviated by floodproofing and removal facilitates a determination of whether or not a structure floodproofing-removal alternative is economically sound.

The submodel contains cost functions for earthen dikes and concrete floodwalls that permit computation of the costs of such structures as a function of their length and average height. The submodel first calculates the crest elevation of a dike or floodwall segment by adding a specified freeboard to the design flood stage. The cost function is then used to calculate the cost of the dike or floodwall segment. The dike-floodwall algorithm facilitates the determination of the total cost of a dike-floodwall alternative for a subreach or a reach. Comparison of the annualized dike-floodwall costs to the average annual damage that would be eliminated permits a determination of whether or not the dike-floodwall approach is economically sound.

The costs of major channel modifications are computed as a function of factors such as the length of the channelized reach; the depth, bottom width, and side slopes of the channel; and the cost of acquiring the land to construct the modified channel. The channel-modification algorithm facilitates the determination of the total cost of a major channel modification for a subreach or a reach. Comparison of the annualized channel modification cost to the average annual monetary damages that would be eliminated as a result of the channel modification permits the determination of whether or not such a structural alternative is economically sound. Use of the Flood Economics Submodel requires prior determination of the depth, bottom width, and side slope of each channel segment. Accordingly, a method was developed for estimating the channel geometry as a function of the size of the area tributary to channelized reach, the slope of the channelized reach, and the magnitude of the 100-year recurrence interval discharge which the channel is intended to convey without being overtopped.

Table 72 identifies up to 66 parameters that may be required, depending on the intended application, to operate the Flood Economics Submodel and indicates the primary source of the numerical value for each of the parameters. These input parameters may be broadly grouped into the following categories: basic cost and economic data applicable to all reaches; reach identification information; reach datum information; reach economic data; reach physical data; subreach identification information; subreach flood event data; subreach physical and economic information; dike-floodwall segment physical and economic data; and channel modification physical and economic data.

Water Quality Submodel

The principal function of the Water Quality Submodel as used in the Menomonee River watershed planning program is to simulate the time-varying concentration, or levels, of the following nine water quality indicators at selected points throughout the surface water system of the watershed: temperature, dissolved oxygen, fecal coliforms, phosphate-phosphorus, total dissolved solids, carbonaceous biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrogen, and nitrite-nitrogen. These indicators were selected because they are directly related to the water quality standards that support the adopted water use objectives set forth in Chapter II of Volume Two of this report.

The concentration of a particular water quality constituent in the surface waters of the watershed at a particular point and time is a function of three factors. The first is the temporal and spatial distribution of runoff—surface or overland runoff, interflow and baseflow—which determines the amount of water available to transport a potential pollutant to and through the surface water system. The second factor is the nature and use of the land, with emphasis on those features that affect the quantity and quality of point and diffuse sources of pollutants. For example, a portion of the watershed that supports agricultural activity is a nutrient source for the surface waters. The third factor is the characteristics of the stream

Table 72

PARAMETERS REQUIRED FOR EACH REACH SIMULATED WITH THE FLOOD ECONOMICS SUBMODEL

Parameter Type	Parameter Identification Number	Parameter Identification Symbol	Definition or Meaning	Unit	Primary Source of Numerical Value
Basic Cost and Economic Data Applicable to all Reaches	1	ECLIFE	Economic Life	Years	--
	2	ANNINT	Annual interest rate as a decimal fraction	None	Current financing costs to governmental units and agencies
	3	ADJDC	Factor to adjust earthen dike capital costs from base year to current year	None	Engineering News Record Construction cost index
	4	ADJFC	Factor to adjust concrete floodwall capital costs from base year current year	None	
	5	ADJCC	Factor to adjust channel modification costs from base year to current year	None	
	6	OMDIKE	Annual operation and maintenance costs of dikes	$1000's/ mile	--
	7	OMWALL	Annual operation and maintenance costs of floodwalls	$1000's/ mile	--
	8	OMCHAN	Annual operation and maintenance costs of channelized reaches	$1,000's/ mile	Local experience
	9	VRATIO	Ratio of market value of structure to market value of structure plus land	None	Local assessors
	10	TITLE	State location and purpose of simulation run	None	--
Reach Identification	11	NIDENR	Identification number	None	Arbitrary
	12	NCIVIL	Civil Division code for land within reach	None	Base Map
	13	NAADAM	Indicator to denote if average annual flood damages are to be computed	None	0: No 1: Yes
Reach Datum Information	14	IDMGR	Indicator to denote datum conversion desired for structure elevations	None	Indicator Values: 0: No datum conversion -1: MSL datum input and local datum desired output +1: Local datum input and MSL datum desired output
	15	IDMSTG	Indicator to denote datum conversion desired for flood event stages	None	
	16	IDMDF	Indicator to denote datum conversion desired for dike-floodwall elevations	None	
	17	IDMCH	Indicator to denote datum conversion desired for channel modification elevations	None	

Table 72 (continued)

Parameter Type	Parameter Identification Number	Parameter Identification Symbol	Definition or Meaning	Unit	Primary Source of Numerical Value
Reach Datum Information (continued)	18	DTMCT	The algebraic difference between MSL datum and local datum	Feet	Datum equation
Reach Standard Economic Data	19	RESMVS	Market value of residential structure and site excluding structure contents (default value)	$1000's	Real estate appraisals
	20	UMVLAS	Market value of riverine land along dike-floodwall segment or channelized reach (default value)	$1000's/ acre	
	21	FPCOSS	Cost of floodproofing residential structure (default value)	$1000's	Literature and area construction practices
	22	RECOSS	Cost of residential structure demolition or removal, site restoration, and land-scaping (default value)	$1000's	Local contractors
Reach Standard Physical Data	23	VDBT1S	Vertical distance between basement floor and first floor elevation of a structure (default value)	Feet	Area construction practices
	24	VDGT1S	Vertical distance between ground grade at main entrance and first floor grade (default value)	Feet	Field sample data
	25	FREEBS	Dike or floodwall freeboard to be added to design flood stage to establish dike or floodwall crest elevation (default value)	Feet	Adopted water control facility standards
	26	THCONC	Thickness of concrete to be used in channel modification	Feet	Local construction practice
Subreach Identification	27	NSUBRE (NSUB)	Identification Number	None	Arbitrary
	28	NDAM	Indicator to denote if flood damages are to be computed	None	Established by program user to reflect purpose of run
	29	NFPR	Indicator to denote if flood-proofing and structure removal costs are to be computed	None	
	30	NDFW	Indicator to denote if dike and floodwall costs are to be computed	None	
	31	NCHAN	Indicator to denote if channel modification costs are to be computed	None	0: No 1: Yes
	32	FREEBA (NSUB)	Dike or floodwall freeboard to be added to design flood stage to establish dike or floodwall crest elevation	Feet	Adopted water control facility standards or special conditions
	33	NDESFL (NSUB)	Identification number of single design flood event for which dike and floodwall costs are to be computed	None	--

Table 72 (continued)

Parameter Type	Parameter Identification Number	Parameter Identification Symbol	Definition or Meaning	Unit	Primary Source of Numerical Value
Subreach Flood Event Data	34	NIDENF(NF)	Identification Number	None	Arbitrary
	35	NDATE(NF)	Date or other flood event descriptor (optional)	None	--
	36	RECUR(NF)	Recurrence interval (optional)	Years	--
	37	STAGE(NF)	Peak Stage	Feet	--
	38	DISCH(NF)	Discharge corresponding to peak stage (optional)	cfs	--
Structure Physical and Economic Data	39	NIDENS(NS)	Identification Number	None	Arbitrary
	40	NTYPES(NS)	Indicator to denote structure type	None	1: single family residence 10: two-family residence 20: multi-family residence 30: mobile home 40: residence under construction 100: business-commercial structure 200: manufacture-industrial structure 300: school 400: church 500: other public structure 600: other private structure 700: other structure
	41	NBANK(NS)	Indicator to denote left or right bank location (optional)	None	1: left bank 2: right bank
	42	NSEWER(NS)	Indicator to denote if secondary flooding is likely to occur, that is, if basement will flood by sanitary sewer back up, storm water backup, wall seepage, etc., when flood stage exceeds basement floor elevation	None	0: secondary flooding will not occur 1: secondary flooding will occur
	43	DISHOR(NS)	Shortest horizontal distance from center of river to riverward face of structure (optional)	Feet	Topographic map or aerial photograph
	44	ELEVGR(NS)	Ground grade at main entrance of structure	Feet	Topographic map or survey data
	45	VDGT1A(NS)	Vertical distance between ground grade at main entrance and first floor grade	Feet	Field data on representative structures
	46	VDBT1A(NS)	Vertical distance between basement floor and first floor elevation	Feet	Field sample data
	47	RESMVA	Market value of residential structure and site excluding structure contents	$1000's	Real estate appraisals
	48	RECOSA(NS)	Cost of residential structure demolition or removal, site restoration and landscaping	$1000's	-1: RECOSS 0: Salvage value will cover cost Local construction practices and physical characteristics of individual structure
	49	FPCOSA(NS)	Cost of floodproofing residential structure	$1000's	-1, 0: FPCOSS Local construction practices and physical characteristics of individual structure

Table 72 (continued)

Parameter Type	Parameter Identification Number	Symbol	Definition or Meaning	Unit	Primary Source of Numerical Value
Dike-Floodwall Segment Physical and Economic Data	50	NIDEDF(NDF)	Identification number	None	Arbitrary
	51	NTYPDF(NDF)	Indicator to denote dike or floodwall	None	1: earthen dike 2: concrete floodwall
	52	XLENDF(NDF)	Length of segment	Feet	Preliminary layout of floodwall system on topographic map
	53	ELEDF1(NDF)	Ground grade at one end of segment	Feet	
	54	ELEDF2(NDF)	Ground grade at other end of segment	Feet	
	55	UMVLAA(NDF)	Market value of riverine land along dike-floodwall alignment	\$1000's/ acre	Real estate appraisals
Channel Modification Segment Physical and Economic Data	56	NIDECH(NCH)	Identification number	None	Arbitrary
	57	ELCONC(NCH)	Elevation of concrete side-walls above concrete invert	Feet	--
	58	XLENCH(NCH)	Length of channelized segment	Feet	--
	59	ELECHU(NCH)	Proposed invert grade at upstream end of channel-ized segment	Feet	--
	60	ELECHD(NCH)	Proposed invert grade at downstream end of channelized segment	Feet	--
	61	BANKUP(NCH)	Existing bank grade at upstream end of channel-ized segment	Feet	--
	62	BANKDN(NCH)	Existing bank grade at downstream end of channelized segment	Feet	--
	63	CHANBW(NCH)	Width of channel bottom	Feet	--
	64	SLCHSW(NCH)	Slope of channel sidewalls	Feet Horizontal/ 1 Foot Vertical	--
	65	CMWITH(NCH)	Construction and maintenace width parallel to and on each side of modified channel segment	Feet	--
	66	CMVLA(NCH)	Market value of riverine land along channelized segment	\$1000's/ acre	Real estate appraisals

Source: SEWRPC.

system which determine the rate and manner in which a potential pollutant is either assimilated or transported from the watershed.

Simulation of the above three factors that influence instream water quality requires a large and diverse data base. As shown on Figure 64, operation of the Water Quality Submodel requires the input of four data sets—meteorological, channel, diffuse source and point source—as well as output from the Hydrologic Submodel. Table 69 identifies the six categories of historic meteorological data sets that are input directly or indirectly to the Water Quality Submodel and notes the use of each data set. The hydraulic portion of the channel data requirements for the Water Quality Submodel are identical to that required for Hydraulic Submodel 1, as discussed earlier in this chapter and as set forth in Table 71. In addition a considerable amount of non-hydraulic channel data must be provided. This data consists primarily of water quality parameters and coefficients such as the maximum benthic algae concentration and the deoxygenation coefficient for each reach.

The basic physical unit on which the Hydrologic Submodel operates is called the "hydrologic-water quality land segment." A hydrologic-water quality land segment is defined as a surface drainage unit that exhibits up to three unique combinations of meteorological parameters, such as precipitation and temperature; land characteristics, such as percent imperviousness, soil type, slope, and crop and other vegetative cover; and land management practices such as contour plowing on agricultural land. Hydrologic-water quality land segments are identified by using hydrologic land segments as the base and incorporating consideration of additional factors likely to influence the washoff of pollutants from the land surface.

A set of diffuse pollution source data is required for each constituent that is to be modeled on each hydrologic-water quality land segment type. Each set of data contains daily land loading rates for the pervious and impervious portions expressed as a weight per unit area and a loading limit for the pervious and impervious areas expressed in weight per unit area of land surface. The diffuse source data set for each land segment also contains the concentration of the constituent in the groundwater flow from the segment to the stream system. Each point source of pollution similarly requires a data set consisting of identification of the river reach to which the source discharges, a series of semimonthly volumetric flow rates and a series of corresponding concentrations for each of the constituents to be modeled. The final category of input to the Water Quality Submodel is output from the Hydrologic Submodel which consists of hourly runoff volumes from the pervious and impervious portion of each hydrologic land segment as well as hourly groundwater discharges to the stream system.

For the purpose of describing the operation of the Water Quality Submodel, the simulation process may be viewed as being composed of a land phase and a channel phase, each of which is simulated on an hourly basis. In the land phase, the quantity of a given constituent that is available for washoff from the land at the beginning of a runoff event is equal to the amount of material remaining on the land surface after the last runoff event plus the net amount of material that has accumulated on the land surface since the last runoff event. The hourly quantity of washoff from the land to the stream system during a runoff event is proportional to the amount of material on the land surface at the beginning of the interval and is also dependent on the hourly runoff rate. The above procedure is not used to simulate the temperature and dissolved oxygen of land runoff. The model assumes that the temperature of the runoff is equal to atmospheric temperature and the runoff is fully saturated with dissolved oxygen. Pervious surface runoff and impervious surface runoff during and immediately after rainfall or rainfall-snowmelt events are the two mechanisms for transporting accumulated diffuse source constituents from the land surface to the stream system. Groundwater flow is the mechanism for continuously transporting potential pollutants to the stream system from the subsurface of the watershed.

Operating on a reach-by-reach basis, the channel phase of the Water Quality Submodel uses kinematic routing to determine the inflow to, outflow from, and net accumulation of flow within each reach on an hourly basis. This is followed by a summation over the hourly interval of all mass inflows and outflows of each water quality constituent so as to determine an average concentration throughout the reach based on the assumption of complete, instantaneous mixing. The biochemical processes are then simulated for a one-hour period so as to yield a reach concentration of each constituent for the end of the period. The above channel phase computations are then repeated within the reach for subsequent time intervals and also are repeated for all other reaches.

DATA BASE DEVELOPMENT

The largest single work element in the preparation and application of the hydrologic-hydraulic-water quality-flood economics model is data base development which consists of the acquisition, verification, and coding of data needed to operate, calibrate, test, and apply the model. The model data base for the Menomonee River watershed is a file of information that quantitatively depicts the characteristics or condition of the surface water system of the watershed.

As shown schematically on Figure 64, application of the model requires the development of an input data base composed of the following six distinct categories of information: meteorological data, land data, channel data, riverine area structure data, diffuse source data and point source data. Each of the six data categories provides input to at least one of the five submodels. Of the six input data sets, the meteorological data set is the largest because it contains 35 years of semimonthly, daily, or hourly information for seven meteorological data types. The meteorological data set is also the most critical in that experience with the model indicates that simulated discharges, stages, and water quality levels are very sensitive to how well the meteorological data set—particularly precipitation—represents historical meteorological conditions.

With respect to the origin, the data in the data base are largely historic, in that they are based on existing records of past observations and measurements. For example, the bulk of the meteorological data in the data base are historic in that they are assembled from National Weather Service records. Some of the data in the data base are original in that they were obtained by field measurements made during the watershed planning program. Most of the channel data, for example, were obtained by field surveys conducted during the course of the study. A small fraction of the data in the data base are synthetic in that they were calculated from other readily available historic data. Calculated data sets were used when historic data were not available and it would have been impossible or impractical to obtain original data. The solar radiation data used, for example, are synthetic in that it was necessary to compute these data from historic percent sunshine measurements because of the absence of long-term historic radiation observations in or near the watershed coupled with the impossibility of developing long-term original solar radiation data.

A distinction should be drawn between input data and calibration data. The six categories of data identified above constitute the input data for the model and constitute the data base needed to operate the various submodels in the model. Calibration data, which are discussed in a subsequent section of this chapter, are not required to operate the model, but are vital to the calibration of the model. The principal types of calibration data are streamflow, flood stage, and water quality.

Each of the six types of input data, as well as the validation data, are described separately in the following sections. The origin of each data set is described as are the procedures used to verify and code the information. In the case of some of the data types, the means of acquisition have been described in earlier chapters of this report and, with the exception of a brief cross-reference, will not be repeated in this chapter.

Meteorological Data

As shown in Table 69, the following seven types of meteorological data are required as direct input to the Hydrologic and/or Water Quality Submodels: hourly precipitation, daily maximum-minimum temperature, daily wind movement, daily solar radiation, daily dewpoint temperature, daily potential evaporation, and daily cloud cover. Map 28 shows the nine National Weather Service meteorologic observation stations located in or near the watershed and the Thiessen polygon network which was constructed for the purpose of delineating the geographic area to be represented by each station. Most of the watershed lies within the Germantown, Mt. Mary, and West Allis polygons and, therefore, the daily precipitation and maximum-minimum temperature data for these three stations were selected as being most representative of the watershed. Hourly precipitation data for the Milwaukee and Hartford stations were used to disaggregate daily precipitation totals for the Mt. Mary, West Allis, and Germantown stations. Other meteorological data sets such as wind movement and dewpoint which were available only for the Milwaukee station were applied to the entire watershed. Therefore, the meteorological data base for the watershed is drawn entirely from historic data from three in-watershed stations—Germantown, Mt. Mary, and West Allis—and two out-of-watershed stations—Milwaukee and Hartford.

The process used to assemble the data base beginning with the National Weather Service data is schematically depicted in Figure 69. Selected information about each of the meteorological data sets is presented in Table 5. Meteorological data sets were developed for the 35-year period from 1940 through 1974. January 1, 1940, was selected as the beginning date for the data sets since it marks the beginning of hourly observations at the Milwaukee station.

Hourly Precipitation: Most of the hourly and daily precipitation data used to construct the precipitation data sets in the meteorological data base were obtained by the Commission directly from the National Climatic Center located in Asheville, North Carolina—the official repository for National Weather Service data. Data obtained from the National Climatic Center for the period prior to 1948 were received in published form, whereas post-1948 data were obtained on magnetic tape. Hourly and daily precipitation data received from the National Climatic Center were supplemented with data published in National Weather Service reports.

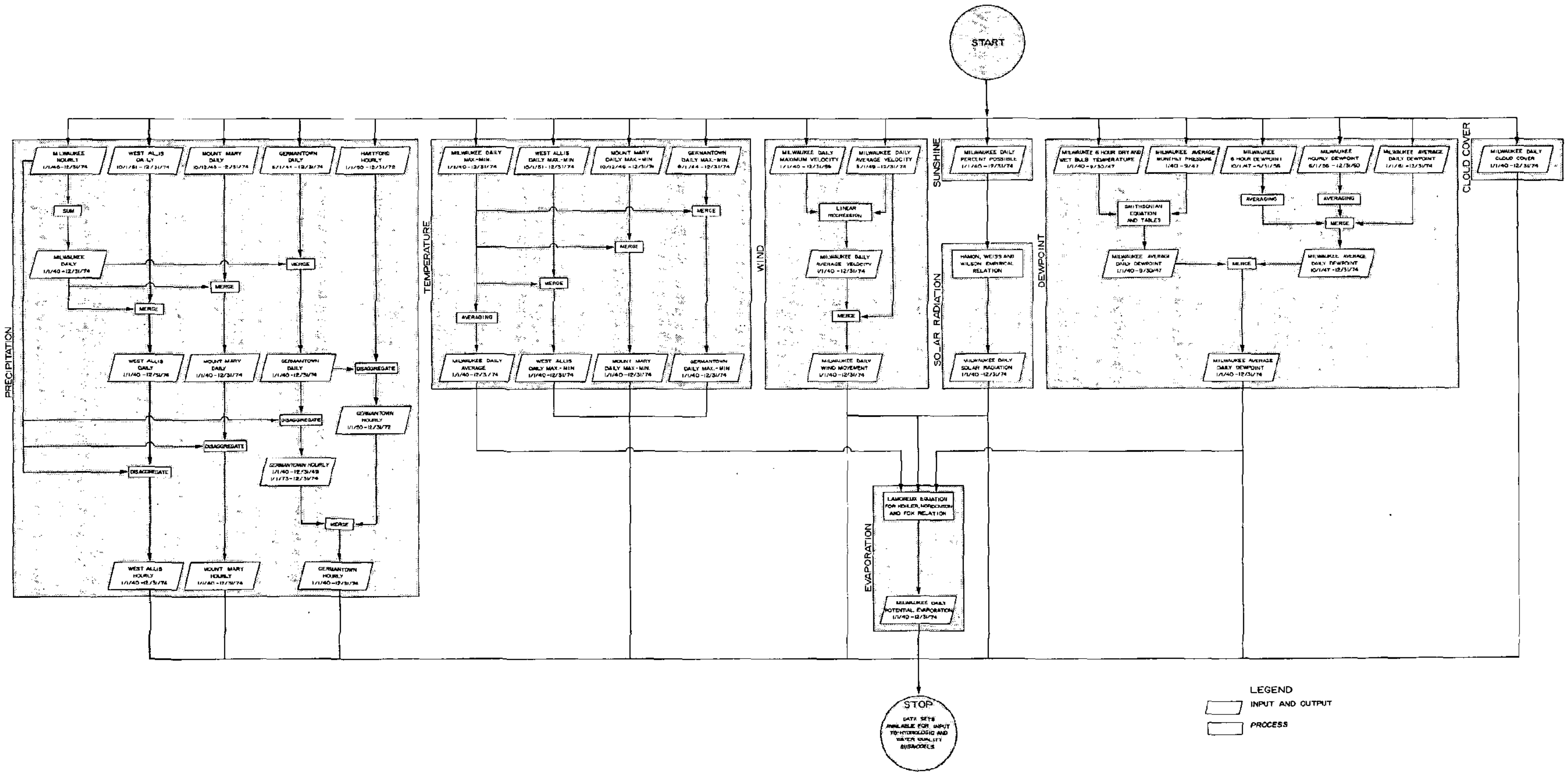
The precipitation data were first reformatted so as to match the input requirements of the model. Various contingency checks were then conducted including identification of missing dates and comparison of daily, monthly, and yearly totals from the National Climatic Center data with daily, monthly, and yearly totals published in National Weather Service reports. The end of the above procedures was complete, verified hourly and daily precipitation data for the period January 1940 through December 1974 at Milwaukee; hourly precipitation data for the period January 1950 through December 1972 at Hartford; daily precipitation data for the period June 1944 through December 1974 at Germantown; daily precipitation data for the period October 1946 through December 1974 at Mt. Mary; and daily precipitation data for the period October 1951 through December 1974 at West Allis.

The historic precipitation data for four stations—Milwaukee, Germantown, Mt. Mary, and West Allis—were subjected to a double mass curve analysis[16] in order to identify the possible presence of significant nonmeteorological trends in the historic data which would require application of compensating corrections. Examples of nonmeteorologic factors that may cause trends in the precipitation data are changes in gage location, alterations in equipment or monitoring techniques, and alterations in the immediate surroundings such as vegetation or buildings. Annual historic precipitation at each of the four stations for the period January 1952 through December 1975 was used for the analysis with the period of record being selected as the longest time interval during which all stations were in operation. The double mass curve for each station consists of a graph on arithmetic scales of cumulative annual precipitation for the station versus cumulative annual precipitation based on the mean of five stations. A linear relationship is indicative of the absence of nonmeteorologic effects whereas a pronounced discontinuity in the double mass curve for any station indicates the occurrence of a nonmeteorologic

[16] *American Society of Civil Engineers, Hydrology Handbook, Manual of Engineering Practice—No. 28, January 1949, pp. 12-15.*

Figure 69

PROCESS USED TO DEVELOP THE METEOROLOGICAL DATA SETS FOR THE MODEL



Source: SEWRPC.

effect in the record. Based on the analysis, it was concluded that there were no significant nonmeteorologic influences in the historic precipitation records for any of the five meteorologic stations used to assemble the data base for the model.

The next step in the development of the precipitation data sets was use of the daily data for Milwaukee to extend the West Allis records back from October 1951 to January 1940; the Mt. Mary records back from October 1946 to January 1940; and the Germantown records back from June 1944 to January 1940. This extension procedure yielded precipitation data sets consisting of 35 years—January 1940 through December 1974—of daily data at Germantown, Mt. Mary, and West Allis.

Inasmuch as the Hydrologic Submodel requires hourly precipitation data as input, the hourly precipitation data for Milwaukee were then used to disaggregate the 35 years of daily data at Mt. Mary and West Allis into hourly data. Milwaukee hourly data were also used to develop hourly data for Germantown for the period from January 1940 through December 1949 and for the period January 1973 through December 1974. Hartford hourly data, which were available for the period January 1950 through December 1972, were used to disaggregate Germantown daily data to hourly data for that period.

This completed the development of the necessary precipitation data sets. During the process of developing the precipitation data sets, all of the original data sets as well as those derived from them were loaded on a magnetic disc file in the format required by the model. Table 73 indicates the identification numbers, names, frequency, and time interval for each of the precipitation data sets that were placed on the computer system file. The only precipitation data sets used on the Menomonee River watershed during operation of the two submodels requiring meteorological data—the Hydrologic Submodel and the Water Quality Submodel—are the January 1940 through December 1974 hourly data sets for Germantown, Mt. Mary, and West Allis.

Daily Maximum-Minimum Temperature: The bulk of the daily maximum-minimum temperature data used to assemble the temperature data sets in the meteorological data base were obtained by the Commission directly from the National Climatic Center. Data for the period prior to 1948 were received in published form and post-1948 data were received on magnetic tape. Temperature data received from the Center were supplemented, as needed, with data published in National Weather Service reports.

The temperature data were first reformatted to conform to the input requirements of the model, and then a series of contingency checks was conducted including identification of missing dates and comparisons of the National Climatic Center data with that published in National Weather Service reports. The end result of the above procedure was complete, verified daily maximum-minimum temperature data sets for the period January 1940 through December 1974 at Milwaukee; for the period October 1951 through December 1974 at West Allis; for the period October 1946 through December 1974 at Mt. Mary; and for the period June 1944 through December 1974 at Germantown.

The Milwaukee record was then used, as shown in Figure 69, to extend the West Allis, Mt. Mary, and Germantown maximum-minimum temperature data sets back to 1940. This extrapolation assumes that, in the absence of actual historic temperature data at West Allis, Mt. Mary, and Germantown, the Milwaukee data provides an acceptable approximation.

This completed the development of the necessary daily maximum-minimum temperature data sets. All of the historic data as well as the derived data were placed on a magnetic disc file in the Commission computer facility during the process of developing the data sets. Table 73 indicates the identification numbers, names, and time interval for each of the temperature data sets that were placed on the computer system file. The only temperature data sets used during operation of the Hydrologic and Water Quality Submodels were the January 1940 through December 1974 daily maximum-minimum temperature data sets for West Allis, Mt. Mary, and Germantown.

Daily Wind Movement: Wind data used to develop the daily wind movement data set were obtained from the published reports of the National Weather Service. The data were for the Milwaukee station and consisted of maximum daily wind speed for the 20-year period January 1940 through December 1959 and average daily wind speed for the 26-year period from August 1949 through December 1974.

The data were first checked for completeness and then a regression analysis was applied to the historic nine year period—January 1951 through December 1959—for which both average daily wind speed and maximum daily wind speed data were available. The result of the analysis was a linear equation giving average daily wind speed as a function of maximum daily wind speed. This equation was then used to extend the average daily wind speed values back 10 years from August 1949 to January 1940. The result was a 35-year—January 1940 through December 1974—data set consisting of average daily wind speed at Milwaukee.

The next step in the development of the wind data set was to apply an adjustment for elevation above the ground surface. The historic average daily wind speed data and, therefore, also the synthetic average daily wind speed data are for an elevation of about 20 feet above the ground surface at the Milwaukee station. The Hydrologic and Water Quality Submodels require wind speed for a position of approximately two feet above the ground at which elevation wind velocity will be significantly less than at 20 feet because of the drag exerted by the ground surface on air moving above and essentially parallel to that surface. The amount of adjustment to be applied was

Table 73

SELECTED INFORMATION OF DATA SETS USED FOR THE HYDROLOGIC SUBMODEL AND HYDRAULIC SUBMODEL 1

Data Category	Data Type	Index Number of Data Set	Geographic Reference of Data			Period of Data Set						Duration of Data Set (Years)
			Name	NWS I.D. Number	USGS I.D. Number	From Month	From Day	From Year	To Month	To Day	To Year	
Meteorological	Precipitation-Hourly	1	Milwaukee	5479	–	1	1	40	12	31	74	35
		2	Germantown	3058	–	1	1	40	12	31	74	35
		3	Mt. Mary	5474	–	1	1	40	12	31	74	35
		4	West Allis	9046	–	1	1	40	12	31	74	35
		5	Union Grove	8723	–	7	1	48	12	31	74	27
		6	Hartford	3453	–	1	1	50	12	31	72	23
		7	West Bend	9050	–	1	1	65	12	31	74	10
	Solar Radiation-Daily	41	Milwaukee	5479	–	1	1	40	12	31	74	35
	Potential Evaporation-Daily	47	Milwaukee	5479	–	1	1	40	12	31	74	35
	Maximum-Minimum Temperature-Daily	51	Milwaukee	5479	–	1	1	40	12	31	74	35
		52	Germantown	3058	–	1	1	40	12	31	74	35
		53	Mt. Mary	5474	–	1	1	40	12	31	74	35
		54	West Allis	9046	–	1	1	40	12	31	74	35
		55	Union Grove	8723	–	10	1	63	12	31	74	11
		57	West Bend	9050	–	1	1	65	12	31	72	10
	Wind Movement-Daily	91	Milwaukee	5479	–	1	1	40	12	31	74	35
	Dewpoint Temperature-Daily	96	Milwaukee	5479	–	1	1	40	12	31	74	35
	Precipitation-Daily	102	Germantown	3058	–	1	1	40	12	31	74	35
		103	Mt. Mary	5474	–	1	1	40	12	31	74	35
		104	West Allis	9046	–	1	1	40	12	31	74	35
		105	Union Grove	8723	–	7	1	48	12	31	74	27
		107	West Bend	9050	–	1	1	65	12	31	72	10
Land	Land Parameters	141	–	–	–	–	–	–	–	–	–	–
	Land Surface Runoff	151	Segment 1	–	–	1	1	40	12	31	74	35
		152	Segment 2	–	–	1	1	40	12	31	74	35
		153	Segment 3	–	–	1	1	40	12	31	74	35
		154	Segment 4	–	–	1	1	40	12	31	74	35
		155	Segment 5	–	–	1	1	40	12	31	74	35
		156	Segment 6	–	–	1	1	40	12	31	74	35
		157	Segment 7	–	–	1	1	40	12	31	74	35
		158	Segment 8	–	–	1	1	40	12	31	74	35
		159	Segment 9	–	–	1	1	40	12	31	74	35
		160	Segment 10	–	–	1	1	40	12	31	74	35
		161	Segment 11	–	–	1	1	40	12	31	74	35
		162	Segment 12[a]	–	–	1	1	40	12	31	74	35
		163	Segment 13[a]	–	–	1	1	40	12	31	74	35
Channel	Channel Parameters	142	–	–	–	–	–	–	–	–	–	–
Calibration and Testing	Streamflow-Daily	143	Oak Creek Gage	–	04087204	10	1	63	9	30	73	10
		144	Root River Canal Gage	–	04087233	10	1	63	9	30	73	10
		145	Menomonee River Gage	–	04087120	10	1	61	9	30	74	13
		146	New Fane Gage	–	04086200	04	26	68	9	30	73	5

[a] *Additional land segment types created for future condition model runs.*

Source: SEWRPC.

determined using the power law[17] which states that:

$$V_2/V_{20} = (Z_2/Z_{20})^K$$

where V_{20} is the wind speed at 20 feet above the ground, Z_2 is 2.0 feet, Z_{20} is 20 feet, K is an exponent that depends on the nature of the ground surface and atmosphere stability, and V_2 is the desired wind speed at two feet above the ground. A relatively wide range of K values is to be expected throughout the watershed, but a range of K values of 0.10 to 0.30 was selected as being most representative. For K values of 0.10, 0.20, and 0.30, computed V_2/V_{20} values are 0.79, 0.63, and 0.50. Based on this analysis, an average wind speed adjustment factor of 0.65 was used to reduce the wind speed data to expected average daily wind speeds for conditions of two feet above the ground surface.

The data set was then converted to daily wind movement at Milwaukee, formatted so as to conform with the input requirements of the model and placed on a magnetic disc file in the Commission computer facility. The identification number, name, and other pertinent information about that file are set forth in Table 73. The Milwaukee station daily wind movement data set was used during operation of the Hydrologic and Water Quality Submodels for the entire watershed because of the insufficient in-watershed wind data.

Daily Solar Radiation: Because of the lack of historic daily solar radiation observations in or near the watershed, daily solar radiation was calculated as a function of daily percent possible sunshine as measured by the National Weather Service at the Milwaukee station. Daily percent possible sunshine data at Milwaukee for the period January 1965 through December 1973 were obtained on magnetic tape from the National Climatic Center, whereas data for the periods January 1940 through December 1964 and January 1974 through December 1974 were obtained directly from the National Weather Service reports.

The percent sunshine data were formatted to conform with the input requirements of the computer program described below and then contingency checks were conducted including identification of missing dates. The end result of the above procedure was a complete, verified daily percent sunshine data set for the 35-year period of January 1940 through December 1974.

The percent sunshine data set was then used to calculate 35 years of daily solar radiation values for Milwaukee according to the empirical method developed by Hamon, Weiss, and Wilson.[18] This graphical technique determines daily solar radiation at the ground surface, expressed in units of langleys per day, as a function of percent of possible sunshine, latitude, and time of year. The percent of possible sunshine parameter serves as a measure of the cumulative effect of factors such as cloud cover, dust, and smoke that determine what fraction of the solar radiation incident on the earth's atmosphere reaches the earth's surface. The graphical method developed by Hamon, Weiss, and Wilson is incorporated in a computer program provided by Hydrocomp, Inc., and modified by the Commission staff which was used to do the calculations.

Prior to using the above technique to calculate Milwaukee daily solar radiation from Milwaukee daily percent possible sunshine, the Hamon, Weiss, and Wilson equation and the computer program were tested using historic daily percent possible sunshine and daily solar radiation for the Madison, Wisconsin, National Weather Service station. Madison percent possible sunshine data for the months of February and August during the 10-year period from 1964 through 1973 were input to the computer program and daily solar radiation values were computed. The February and August data were selected so as to encompass the full range of solar radiation values normally experienced in southern Wisconsin. The computed values compared well with the record values for the same period. For example, the average computed daily solar radiation for February days was 250 langleys which is within 6 percent of the average recorded value of 265 langleys. Similarly, the average computed daily solar radiation for August days was 511 langleys which is within 4 percent of the average recorded value of 491 langleys.

The resulting data set consisting of 35 years of Milwaukee daily solar radiation data was placed on a magnetic disc file in the Commission computer facility. The identification number, name, and other pertinent information about that file are set forth in Table 73. The Milwaukee daily solar radiation data set was assumed to apply to the entire watershed during operation of the Hydrologic and Water Quality Submodels since the Milwaukee station is the only location near the watershed where such data could be synthesized.

Daily Dewpoint Temperature: Daily dewpoint temperature values used to develop the 35-year daily dewpoint temperature data set were obtained directly from published National Weather Service reports for the Milwaukee station with the exception of the eight-year period from January 1940 through September 1947 for which daily dewpoint temperature values were computed from published National Weather Service observations of dry and wet bulb temperature and atmospheric pressure. As shown on Figure 69, the daily dewpoint temperature data for the different portions of the 27-year period from October 1947 through December 1974 were published by the National Weather Service in three different daily formats: six-hour intervals, hourly intervals, and average daily values.

The dewpoint temperature data for the October 1947 through December 1974 period were first checked for

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[17] *R. K. Linsley, M. A. Kohler, and J. L. H. Paulhus, Hydrology for Engineers, Second Edition, 1975, pp. 41-46.*

[18] *R. W. Hamon, L. L. Weiss, and W. T. Wilson, "Insolation as an Empirical Function of Daily Sunshine Duration," Monthly Weather Review, Volume 82, No. 6, June 1954, pp. 141-146.*

completeness and then the six-hour data for the October 1947 through May 1956 period and the hourly data for the June 1956 through December 1960 period were averaged to obtain average daily dewpoint temperature values. In averaging the hourly data, only four observations were used—midnight, 6:00 a.m., noon, and 6:00 p.m.—so as to be consistent with the period of record during which six-hour interval dewpoint temperature values were available. Daily dewpoint temperature values obtained by averaging were merged with the reported average daily dewpoint temperature values to produce a data set consisting of daily dewpoint temperature values for the 27-year period extending from October 1947 through December 1974.

Daily dewpoint temperatures were then calculated for the seven-year period from January 1940 through September 1947 using six-hour interval dry and wet bulb temperatures and average monthly atmospheric pressure as reported by the National Weather Service. The method[19] consists of first applying an equation that gives the vapor pressure of the air as a function of dry and wet bulb temperatures and atmospheric pressure. Then the vapor pressure is entered into a table of temperature versus saturation vapor pressure to determine the dewpoint temperature, that is, the temperature at which air would be saturated at that vapor pressure. This method was used to calculate dewpoint temperatures for six-hour intervals and then these temperatures were averaged to yield the daily dewpoint temperature. The computations were executed by a computer program, written by the Commission staff, that incorporated both the aforementioned equation and the table. The resulting computed daily dewpoint temperature for January 1940 through September 1947 was merged with the daily dewpoint temperature for the October 1947 to December 1974 period, yielding the desired 35-year data set of daily dewpoint temperatures.

The data set was formatted so as to conform with model input requirements and placed on a magnetic disc file in the Commission computer facility. The identification number, name, and other information pertaining to that file are set forth in Table 73. This Milwaukee station data set was applied to the entire watershed during operation of the Hydrologic and Water Quality Submodels.

Daily Potential Evaporation: Because of the lack of historic daily evaporation observations in or near the watershed, daily potential lake or reservoir evaporation amounts at Milwaukee were calculated as a function of the following four meteorologic parameters for Milwaukee: average daily temperature, daily wind movement, daily solar radiation, and average daily dewpoint temperature. The procedures used to develop each of these four data sets were described above.

Kohler, Nordenson and Fox[20] used theoretical relations and field data to develop a graphical procedure for determining daily lake or reservoir evaporation as a function of the above four parameters. Lamoreux[21] developed a mathematical equation equivalent to the graphical procedure, thereby facilitating direct calculation of evaporation. The Commission staff prepared a computer program that uses the Lamoreux formula to calculate daily potential evaporation as a function of average daily temperature, daily wind movement, daily solar radiation, and the average daily dewpoint temperature. These four meteorological parameters for Milwaukee were input to the program for the 35-year period from January 1940 through December 1974 and the corresponding daily potential evaporation values for Milwaukee were computed for that time period.

As a check on the applicability of the methodology to the southeastern Wisconsin area, average monthly and annual potential evaporation values for the 35 years were compared to published average monthly and annual values[22] estimated for Milwaukee based on a long period of historic records at midwestern stations. Average monthly values obtained from the computer program were up to 162 percent too high for the months of January through July and the month of December while the computed values were found to be up to 25 percent too low for the remaining four months. Based on this comparison and subsequent calibration efforts, monthly adjustment factors were incorporated into the computed potential evaporation values, the calculations were repeated for the 35-year period, and the resulting values were found to compare well—within 3 percent on an annual basis and within 15 percent on a monthly basis—with the ASCE Handbook values.

The 35 years of daily potential evaporation values, formatted so as to conform to model input requirements, were placed on a magnetic disc file in the Commission computer facility. The identification number, name, and other information pertaining to that file are set forth in Table 73. The Milwaukee station data set was applied to the entire watershed during operation of the Hydrologic Submodel.

Daily Cloud Cover: Daily cloud cover data at Milwaukee for the period January 1965 through December 1963 were obtained on magnetic tape from the National Climatic Center whereas data for the periods January

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[19] *R. J. List, Smithsonian Meteorological Tables, Sixth Revised Edition, Smithsonian Miscellaneous Collection, Volume 114, Smithsonian Institution Press, Washington, 1949.*

[20] *M. H. Kohler, T. J. Nordenson, and W. E. Fox, Evaporation from Ponds and Lakes, Research Paper No. 38, U. S. Weather Bureau, 1955, 21 pp.*

[21] *W. W. Lamoreux, "Modern Evaporation Formulae Adapted to Computer Use," Monthly Weather Review, January 1962.*

[22] *American Society of Civil Engineers, Hydrology Handbook, Manual of Engineering Practice No. 28, January 1947, pp. 126-127.*

1940 through December 1964 and January 1974 through December 1974 wre obtained directly from National Weather Service reports. The cloud cover data were formatted to conform to the input requirements of the model, and then contingency checks were conducted including identification of missing dates. The end result of the above procedure was a complete, verified daily cloud cover data set for the 35-year period of January 1940 through December 1974.

The resulting data set was placed on a magnetic disc file in the Commission computer facility. The identification number, name, and other pertinent information about that file are set forth in Table 73. The Milwaukee daily cloud cover data set was assumed to apply to the entire watershed during operation of the Water Quality Submodel.

Land Data

As shown on Figure 64, land data are important in that they are needed to operate the Hydrologic Submodel, the output of which influences the four other submodels. Table 70 identifies the 28 land or land-related parameters that are required for each land segment type that is to be simulated. As defined earlier in this chapter, a land segment is a surface drainage unit consisting of a subbasin or a combination of contiguous subbasins that is represented by a particular meteorological station and contains a unique combination of three key land characteristics—soil type, slope, and land use or cover. The four factors—meteorology, soil type, slope, and land use or cover—are considered to be the major determinants of the magnitude and timing of surface runoff, interflow and groundwater flow from the land to the watershed stream system and therefore are the basis for hydrologic land segment identification and delineation. There are other land characteristics that may influence the hydrologic response of the land surface—for example, depth to bedrock, type of vegetation, and density of the storm water drainage system—but the above four land characteristics were selected for use as both the most basic and most representative.

Identification of Hydrologic Land Segment Types: The process used to identify hydrologic land segments in the watershed began with the subdivision of the watershed into subbasins using the procedure described in Chapter V of the volume. As shown on Map 45, a total of 248 subbasins were delineated ranging in size from 0.06 to 1.63 square miles. These subbasins provided the basic "building blocks" for the identification of hydrologic land segments and subsequently, for hydrologic-water quality land segments in the watershed.

Influence of Meteorological Stations: As noted earlier in this chapter, and as shown on Map 28, a Thiessen polygon network was constructed for the watershed and surrounding areas in order to facilitate subdivision of the watershed into areas closest to the Germantown, Mt. Mary, and West Allis meteorological stations. The polygon boundaries were approximated by subbasin boundaries and then each subbasin was assigned to either the Germantown, Mt. Mary, or West Allis meteorological stations. The effect of this was to associate each subbasin with the closest meteorological station and therefore with the station most likely to be representative of the meteorological processes affecting the subbasin.

Hydrologic Soil Group: As discussed in Chapter V of this volume and as illustrated on Map 30, the soils of the Menomonee River watershed have been classified into four hydrologic soil groups, designated A, B, C, and D, based upon those soil properties affecting runoff. In terms of runoff characteristics, these four soil groups range from Group A soil, which exhibits very little runoff because of high infiltration capacity, high permeability, and good drainage, to Group D soils, which generate large amounts of runoff because of low infiltration capacity, low permeability, and poor drainage. Hydrologic soil groups are not assigned to those small, widely scattered areas in the watershed—referred to as "made land"—where the underlying natural soils have been significantly disturbed, covered, or removed as a result of construction activity, quarrying operations, or land fill use. Hydrologic soil group data were used to determine which of the four soil groups, or made land, was dominant within each of the 248 subbasins. For this purpose, the 22-square-mile lower portion of the watershed for which soils data are not available was assumed to be covered with soils in Hydrologic Group C based on the characteristics of the surrounding soils.

Slope: A watershed slope analysis was conducted by determining the ground slope at the center of each U. S. Public Land Survey quarter section. Topographic information required to estimate the ground slope was taken from 1" = 2000' scale, 10' contour interval, U. S. Geological Survey quadrangle maps since they provided the best available uniform coverage for the entire watershed. Although more accurate slope values could have been obtained from either large-scale topographic maps or from Commission soils maps, these sources of information were not used because the resulting accuracy would have exceeded that required by the model. Watershed slopes were found to vary from zero to over 10 percent and, based on the observed distribution of slopes, two slope ranges were selected: zero to 4 percent and over 4 percent. The slope range representative of each subbasin was noted and assigned.

Land Use and Cover: Land use and cover are the characteristics which most effectively reflect man's influence on the hydrologic processes in that land use and cover, particularly in the Menomonee River watershed, are largely the result of man's activities. Table 74 lists the five land use and cover types defined for the purpose of identifying hydrologic land segments. These five land use and cover types encompass the full spectrum of existing conditions in the watershed and, equally important, include planned and other possible future conditions in the watershed.

The land use and cover type most representative of each of the basins was determined and assigned to the subbasin. Several sources of information were used to determine the dominant land use and cover, including

1970 1" = 400' scale Commission aerial photographs and corresponding land use and cover data, Map 11 of this report which shows generalized land use in the watershed, and Map 22 of this report which shows watershed woodland and wetlands.

Resulting Hydrologic Land Segment Types and Hydrologic Land Segments: A strict application of the above process yielded a total of 38 different hydrologic land segment types in the Menomonee River watershed. This number represents a precision of input data exceeding that judged necessary to achieve the desired model accuracy. The original total of 38 different hydrologic land segment types was, therefore, reduced to 16 different land segment types by combining very similar segments and by consolidating made lands and Hydrologic Soil Group C and D soils into a single category. The resulting 16 hydrologic land segment types used to represent the land surface of the Menomonee River watershed for hydrologic-hydraulic simulation are defined in Table 75 in terms of their hydrologic soil grouping, slope, land use or cover, and proximity to a meteorological station.

Subsequent sensitivity studies conducted with the Hydrologic Submodel on land segment types that had different slopes but were identical with respect to proximity to meteorologic station, soil type, and land use or cover revealed no significant difference in runoff for slopes in the 0 to 4 percent category as compared to slopes in the 4 to 10 percent category. Therefore, since the range of ground slopes present in the Menomonee River watershed was not likely to influence the hydrologic response of the land surface, slope was eliminated as a factor in identifying hydrologic land segment types. It also was determined that the hydrologic response of high-density urban areas with separate sewers would be similar to that for high-density areas with combined sewers. Therefore, the distinction between these two types of sewer systems was eliminated as a factor used to identify hydrologic land segment types. The net effect of these modifications was to reduce the number of hydrologic land segment types in the watershed from 16 to 11 as shown in Table 75.

The size and spatial distribution of the 11 hydrologic land segment types in the watershed under 1975 conditions are depicted on Map 79. The map also shows the actual 108 hydrologic land segments, that is, surficial drainage units used as input to the model. Each hydrologic land segment consists of a subbasin or combination of contiguous subbasins that are within the influence of a given meteorological station and contain a unique combination of soil type and land use or cover.

Table 74

LAND USE AND COVER TYPES IN THE MENOMONEE RIVER WATERSHED AS DEFINED FOR THE HYDROLOGIC SUBMODEL

Identification Number	Rural or Urban	Description	Nominal Percent Imperviousness
1	Rural	Agricultural lands, woodlands, wetlands, and unused lands	2
2	Urban	Low density residential with supporting urban uses	20
3	Urban	Medium density residential with supporting urban uses	45
4	Urban	High density residential with supporting urban uses, on separate sewer system	65
5	Urban	High density residential with supporting urban uses, on combined sewer system	65

Source: SEWRPC.

Assignment of Parameters to Hydrologic Land Segment Types

Subsequent to identification of the hydrologic land segment types and delineation of the hydrologic land segments present in the watershed, numerical values were selected for each of the 28 land or land-related parameters required for each of the land segment types. Table 70 indicates that the numerical values were established in a number of ways including direct measurement of watershed characteristics, experience gained through previous application of the Hydrologic Submodel to watersheds having similar geographic and climatologic characteristics as the Menomonee River watershed,[23] information taken from hydrology references, and calibration of the Hydrologic Submodel and Hydraulic Submodel 1 against historic streamflow records. The calibration process, which is the principal means of assigning numerical values to four parameters,[24] is discussed in detail later in this chapter.

Channel Data

Channel conditions including slope and cross-section are important determinants of the hydraulic behavior of a stream system. Channel data, therefore, are needed to operate Hydraulic Submodel 1 and Hydraulic Submodel 2. The data required for Hydraulic Submodel 2 will be discussed prior to that required for Hydraulic Submodel 1 since the amount and detail of channel data required by the former far exceeds that needed for the latter and since the channel data needed for Hydraulic Submodel 1 is based on or derived from the channel data assembled for Hydraulic Submodel 2.

Channel Data for Hydraulic Submodel 2: The following four types of channel data are required as input to Hydraulic Submodel 2: discharge, channel-floodplain cross-sections including the distance between cross-

[23] *For example, refer to: "Simulation of Discharge and Stage Frequency for Flood Plan Mapping in the North Branch of the Chicago River," by Hydrocomp, Inc., for the Northeastern Illinois Planning Commission, February 1971, 75 pp.*

[24] *LZSN, UZSN, INFILTRATION, and INTERFLOW.*

Table 75

HYDROLOGIC LAND SEGMENT TYPES REPRESENTATIVE OF THE MENOMONEE RIVER WATERSHED

Identification Number of Hydrologic Land Segment Type		Most Influential Meteorologic Station			Hydrologic Soil Groups		Slope		Land Use-Cover: Rural	Land Use-Cover: Urban				Subbasins in Watershed Represented by Land Segment Type		
Original Set	Reduced Set[a]	Germantown	Mt. Mary	West Allis	B	C, D, and Made Land	Less Than or Equal to 4 Percent	Greater Than 4 Percent	1 Agricultural Lands, Woodlands, Wetlands, and Unused Lands	2 Low-density Residential With Supporting Uses	3 Medium-density Residential with Supporting Uses	4 High-density Residential with Supporting Urban Uses, on Separate Sewer System	5 High-density Residential with Supporting Urban Uses, on Combined Sewer System	Number	Percent of Total	Comment
A	1	X			X		X		X					17	6.85	Soils, slope, and land use cover are similar to East Branch of Milwaukee River test basin
B	1	X			X			X	X					8	3.23	Soils, slope, and land use cover are similar to East Branch of of Milwaukee River test basin
C	2	X				X	X		X					50	20.15	Soils, slope, and land use cover are similar to rural portion of Oak Creek test basin and most of Root River Canal test basin
D	3	X				X	X			X				9	3.63	Soils, slope, and land use cover are similar to urban portion of Oak Creek test basin
E	4	X				X	X				X			8	3.23	Same as segment 3
F	2	X				X		X	X					12	4.84	
G	5		X			X	X		X					12	4.84	Soils, slope, and land use cover are similar to rural portion of Oak Creek test basin and most of Root River Canal test basin
H	6		X			X	X			X				25	10.07	Same as segment 3
I	7		X			X	X				X			28	11.28	Same as segment 3
J	5		X			X		X	X					8	3.23	
K	6		X			X		X		X				11	4.44	
L	8		X			X		X				X		5	2.02	
M	9			X		X	X			X				9	3.63	Same as segment 3
N	10			X		X	X				X			18	7.26	Same as segment 3
O	11			X		X	X					X		14	5.65	Same as segment 3
P	11			X		X	X						X	14	5.65	
													Total:	248	100.00	

[a] *Assumes that the ground slope range in the watershed and the characteristics of the combined sewers versus separate sewers do not have a significant impact on the hydrologic response of the watershed. The table indicates that the watershed contains five significantly different combinations of hydrologic soil group and land use-cover.*

Source: SEWRPC.

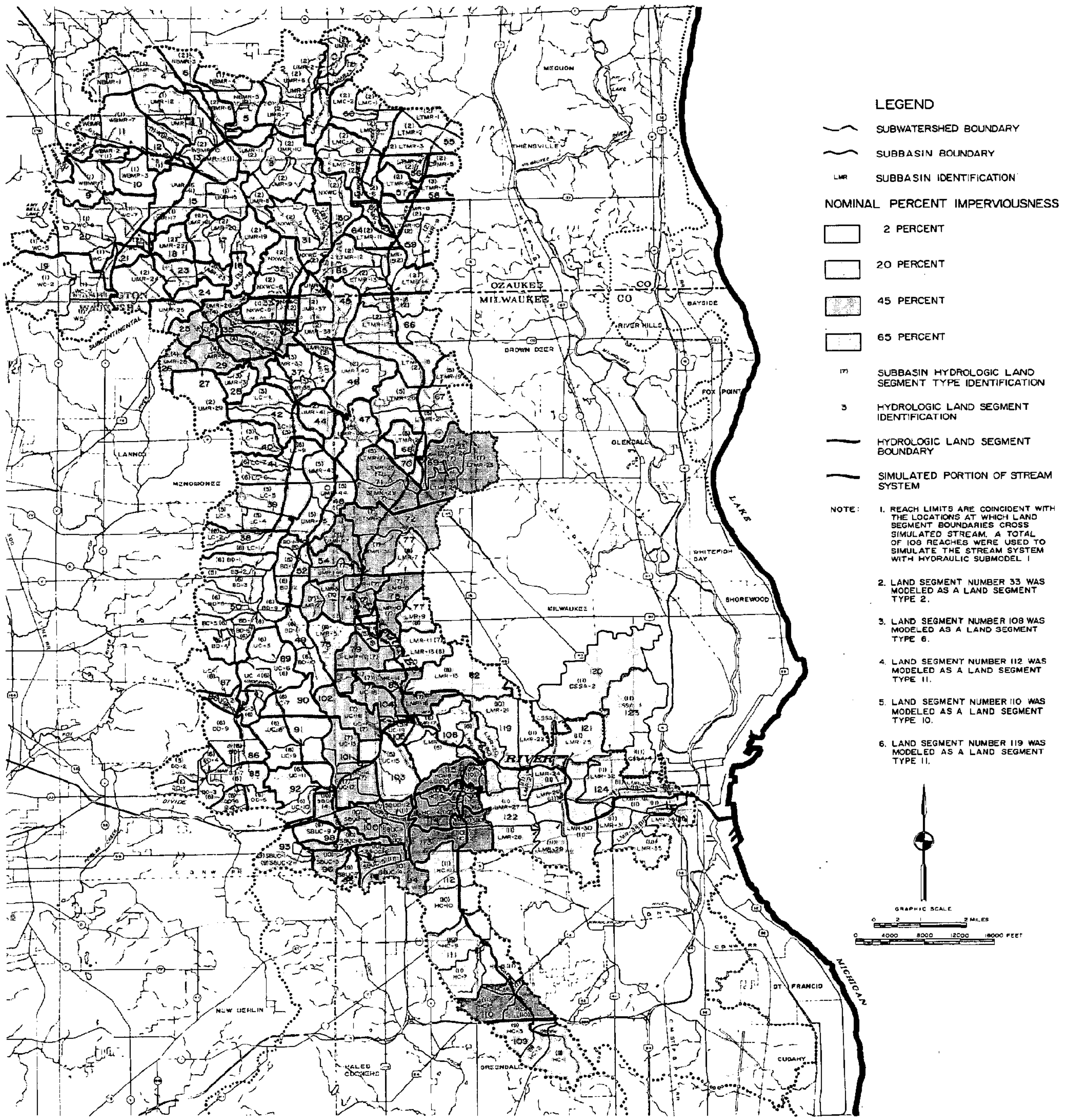
sections, Manning roughness coefficients for the channel and each floodplain or portions of each channel and floodplain, and hydraulic structure—bridge, culvert, and dam—data. Hydraulic structure data includes channel bottom elevations, waterway opening measurements, pier position and shape, profiles along the approach roads and across the structure from one side of the floodlands to the other, and dam crest shape and elevation.

The required discharges are obtained as a result of operating Hydraulic Submodel 1, and performing discharge frequency analyses on those discharges using the log-Pearson Type III technique.[25] The frequency analysis yields flood discharges of a known recurrence interval at various points throughout the watershed stream system. This procedure was used to obtain 2-year, 10-year, 25-year, 50-year, and 100-year discharges which were input to the Hydraulic Submodel 2, which was used to compute the corresponding flood stage profiles. The

[25] *"A Uniform Technique for Determining Flood-Flow Frequencies," Bulletin No. 15, United States Water Resources Council, Washington, D. C. 1967.*

Map 79

REPRESENTATION OF THE MENOMONEE RIVER WATERSHED FOR HYDROLOGIC-HYDRAULIC SIMULATION: 1975



For purposes of hydrologic-hydraulic modeling, the watershed land surface was partitioned into 108 hydrologic land segments and the watershed stream system was subdivided into 108 reaches. Each hydrologic land segment has a particular combination of soil, percent imperviousness, and proximity to a meteorologic station and is used within the hydrologic-hydraulic model to simulate the conversion of rainfall and snowmelt to streamflow. Each stream reach has a unique set of parameters describing channel slope, cross-sectional shape, and flow resistance and is used to simulate the accumulation of runoff from land surface in the stream system and the transport of that flow through the watershed.

Source: SEWRPC.

procedures used to obtain the other three types of data—channel-floodplain cross-sections, Manning roughness coefficients, and hydraulic structure data—required by Hydraulic Submodel 2—are described in detail in Chapter V of this volume. As indicated there, the necessary information, including floodland cross-sections with an average spacing of about 500 feet and physical descriptions of 190 hydraulically significant structures, was obtained for about 72 miles of watershed stream selected for simulation.

Channel Data for Hydraulic Submodel 1: The following three categories of channel data are required as input to Hydraulic Submodel 1, for each river reach that is to be simulated: discharge, channel-floodplain cross-sections including the length and upstream and downstream elevations of the reach represented by each cross-section, and Manning roughness coefficients for the channel and the floodplains. Table 71 lists the 15 channel or channel-related parameters that are input to the submodel for each reach and indicates the primary source of numerical values for each. If lakes or reservoirs are present in the system and are to be modeled, a stage-discharge-cumulative storage table must be provided along with the surface area of the impoundment and other impoundment characteristics.

The types of data required for Hydraulic Submodel 1, are generally quite similar to those required for Hydraulic Submodel 2 in that both require discharges, floodland cross-sections, and Manning roughness coefficients. Submodel input data requirements differ, however, in several significant ways. First, Hydraulic Submodel 2 uses closely spaced floodland cross-sections—an average spacing of 500 feet was used in the watershed modeling—consistent with its primary function of using given discharges to accurately compute flood stages. Hydraulic Submodel 1 uses generalized floodland cross-sections with each representing an average reach length of about 0.7 mile as is consistent with its primary function of calculating discharges. Second, the floodland cross-sections prepared for Hydraulic Submodel 1 are generally representations of the hydraulic-floodplain topography whereas the cross-sections developed for Hydraulic Submodel 2 are more precise. In the latter case, the cross-section shape is defined by up to 100 coordinates whereas in the former case the cross-section is defined by only a channel bottom width, a bank-to-bank width, a channel depth, and a single lateral slope representative of the floodplains on both sides of the channel. Third, Hydraulic Submodel 2 accepts more than one Manning roughness coefficient for each floodplain whereas for Hydraulic Submodel 1 only one coefficient is permitted to represent both floodplains. Fourth, Hydraulic Submodel 2 includes algorithms for calculating the hydraulic effect of a bridge or culvert and associated approach roadways under a variety of upstream and downstream conditions whereas bridge and culvert computations are not included in Hydraulic Submodel 1, except where they are modeled as impounding structures.

The process used to establish numerical values for the channel parameters was initiated by subdividing the 72 miles of stream system selected for simulation into reaches and assigning tributary areas to the reaches. One criterion used to identify reaches is that each reach be relatively homogeneous with respect to floodland cross-sectional shape, channel slope, and channel-floodplain roughness coefficients. Reaches were thus terminated at points of confluence in the stream system, at locations where the tributary area exhibited abrupt changes in land use, and at locations where discharges were to be computed. The most important consideration in determining the minimum allowable reach length was the relationship between the computational time interval, as used in the Hydrologic Submodel and Hydraulic Submodel 1, and the reach flow through time. It is necessary for the computational interval to be approximately equal to or less than the reach flow through time in order for the model to properly perform hydrograph routing. Applying this criterion, it was determined that for the 30-minute computational time interval used in the modeling, the minimum reach length should be about one mile. The net effect of the above factors was the partitioning of the 72 miles of stream system into 108 reaches, as shown on Map 1, having an average length of about 0.7 mile. The first step in the stream system representation process was completed by identifying the size and characteristics of the subbasin or subbasin group immediately tributary to each reach.

The next step in the data preparation process included specification of the type of reach—that is, rectangular or circular—and characterization of the hydraulic aspects of each reach. Seven cross-section-related parameters were assigned on a reach-by-reach basis. Cross-sections were selected from the set of detailed cross-sections prepared for Hydraulic Submodel 2, the selected cross-sections were composited, and one generalized representative cross-section was constructed for each reach. That cross-section was then used to determine numerical values for channel parameters 10 through 13 in Table 3. A procedure similar to the above was used to assign a channel Manning roughness coefficient and a floodplain Manning roughness coefficient to each reach. Coefficients established for Hydraulic Submodel 2 were examined in order to select representative channel and floodplain coefficients for each of the reaches. This completed the assignment of the 15 channel parameters listed in Table 3 and required for operation of Hydraulic Submodel 1.

The resulting data set for Hydraulic Submodel 1 was coded to conform with input format requirements and then placed on punch cards. Such a data set was prepared for each stream system configuration—for example, existing condition and unplanned floodland fill—that was to be simulated.

Riverine Area Structure and Related Data
As depicted on Figure 64, physical and economic data for riverine area structures—residential and commercial buildings—are needed as input to the Flood Economics Submodel along with flood event information and dike-floodwall and channelization data. Table 72 identifies the up to 66 structure, flood event, dike-floodwall, channelization, and related parameters required for each

flood-prone reach for which flood damage, floodproofing-removal costs, dike-floodwall costs, and channelization are to be calculated. This section of the chapter describes the process used to subdivide flood-prone areas into reaches and subreaches and to obtain or assign numerical values to the parameters.

Preparation of submodel input data was initiated with the assignment of basic cost and economic data applicable to all reaches. Flood damage reaches, that is, reaches for which flood economics calculations were executed using the submodel, were then established based partly on historic flood information, collected under the watershed study and described in Chapter VI of this volume, and partly on the results of the hydrologic-hydraulic simulation as described in this chapter. In addition to delineating flood damage reaches so as to encompass areas of existing or potential flood problems, reach boundaries were made coincident with civil division boundaries so as to facilitate the summarization of flood damages and the costs of structure floodproofing-removal, dikes and floodwalls, and channelization by civil division. This approach provides each community with a monetary quantification of both the seriousness of its flood problem and of alternative solutions to that flood problem. The reaches were also selected to encompass areas in which each structure category—for example, single family residential—exhibited similar market values. Each reach was extended out from the river beyond the 100-year recurrence interval flood hazard line so as to encompass both the primary flooding zone—the floodland area adjacent to the channel and subject to overland flooding during a 100-year flood—and the secondary flooding zone—the area contiguous with the primary zone in which basement flooding may occur as a result of sanitary and storm sewer backup.

The next step in submodel data preparation consisted of partitioning the reaches into subreaches, the principal consideration being that the length of each subreach along the river be selected so that each would have approximately uniform flood stages from the upstream end to the downstream end. The implication of this criterion is that steeper streams will have shorter subreaches than streams with flatter slopes. Subreach boundaries were made coincident with hydraulic restrictions such as bridges and culverts as determined with Hydraulic Submodel 2, inasmuch as these locations represented abrupt changes in the flood stage profile. Flood-prone riverine areas having the potential for application of floodproofing-removal measures or for dike-floodwall protection were included in separate subreaches so as to permit a direct comparison of the costs of structural measures to the benefits—reduced flood damages—that would accrue to those measures. The resulting subreaches were delineated on the best available topographic maps, and the necessary subreach identification parameters were assigned.

Output from Hydraulic Submodel 2, consisting of flood stage profiles for a range of recurrence intervals, provided the flood event input data required for each subreach. Structural, physical, and economic information was obtained from large-scale topographic maps, aerial photographs, sample field surveys, and personal interviews. For those subreaches where dike-floodwall or channelization alternatives were considered, the plan of the potential dike-floodwall or channelization systems—as delineated on a topographic map or aerial photograph—was used, in combination with additional information obtained from river bed profiles, to establish the input parameters, thus completing the assignment of numerical values for all parameters. The resulting data set for the Flood Economics Submodel were coded so as to conform to input data requirements and then were placed on punched cards.

Diffuse and Point Source Data

Figure 64 illustrates how diffuse and point source data are required as input to the Water Quality Submodel, along with meteorologic and channel data and output from the Hydrologic Submodel. The choice of initial numerical values for some diffuse source pollution parameters, such as land surface loading rates, was based largely on values reported in the literature for urban and rural areas similar to the Menomonee River watershed.[26,27] Some of these values subsequently were adjusted during the calibration process to improve the correlation between historic and simulated water quality. A set of diffuse source pollution parameters was established for each hydrologic-water quality land segment. Point source input data consisted of daily discharge and water quality values for the four municipal sewage treatment facilities in the watershed, plus data for the Germantown County Line plant which, although it was permanently removed from service in November 1973, was used in the calibration process. Selected information about each of the diffuse and point source data sets, along with information about the meteorologic data sets and output from the Hydrologic Submodel used as input to the Water Quality Submodel, is set forth in Table 76.

The size and spatial distribution of the 11 hydrologic-water quality land segment types in the watershed under 1975 conditions are depicted on Map 80. The map also shows the 56 hydrologic-water quality land segments, that is, surficial drainage units, used as input to the model. Finally, the map also indicates how the 67 lineal miles of channel system above Hawley Road were subdivided into 56 channel reaches for purposes of simulating instream water quality processes.

Calibration Data

The six categories of data discussed above—meteorological, land, channel, riverine area structure, diffuse pollution source, and point pollution source—constitute the total input data for operation of the model that are required

[26] *Hydrocomp, Inc., "Hydrocomp Simulation Programming-Mathematical Model of Water Quality Indices in Rivers and Impoundments," 1972.*

[27] *U. S. Army Corps of Engineers-Seattle District, Environmental Management for the Metropolitan Area Cedar-Green River Basins, Washington, Part II: "Urban Drainage," December 1974, p. 86.*

Table 76

SELECTED INFORMATION ON DATA SETS USED FOR THE WATER QUALITY SUBMODEL

Data Category	Data Type	Index Number of Data Set	Geographic Reference of Data			Period of Data Set						Duration of Data Set (Years)
						From			To			
			Name	NWS I.D. Number	USGS I.D. Number	Month	Day	Year	Month	Day	Year	
Meteorological	Precipitation-Hourly	2	Germantown	3058	–	1	1	40	12	31	74	35
		3	Mt. Mary	5474	–	1	1	40	12	31	74	35
		4	West Allis	9046	–	1	1	40	12	31	74	35
	Solar Radiation-Daily	41	Milwaukee	5479	–	1	1	40	12	31	74	35
	Cloud Cover-Daily	45	Milwaukee	5479	–	1	1	40	12	31	74	35
	Potential Evaporation-Daily	47	Milwaukee	5479	–	1	1	40	12	31	74	35
	Maximum-Minimum Temperature-Daily	52	Germantown	3058	–	1	1	40	12	31	74	35
		53	Mt. Mary	5474	–	1	1	40	12	31	74	35
		54	West Allis	9046	–	1	1	40	12	31	74	35
	Wind Movement-Daily	91	Milwaukee	5479	–	1	1	40	12	31	74	35
	Dewpoint Temperature-Daily	96	Milwaukee	5479	–	1	1	40	12	31	74	35
Land	Impervious Surface Runoff	175	Land Segment 1	–	–	1	1	40	12	31	74	35
		178	Land Segment 2	–	–	1	1	40	12	31	74	35
		181	Land Segment 3	–	–	1	1	40	12	31	74	35
		184	Land Segment 4	–	–	1	1	40	12	31	74	35
		187	Land Segment 5	–	–	1	1	40	12	31	74	35
		190	Land Segment 6	–	–	1	1	40	12	31	74	35
		193	Land Segment 7	–	–	1	1	40	12	31	74	35
		196	Land Segment 8	–	–	1	1	40	12	31	74	35
		199	Land Segment 9	–	–	1	1	40	12	31	74	35
		202	Land Segment 10	–	–	1	1	40	12	31	74	35
		205	Land Segment 11	–	–	1	1	40	12	31	74	35
		208	Land Segment 12	–	–	1	1	40	12	31	74	35
		211	Land Segment 13	–	–	1	1	40	12	31	74	35
	Overland Flow Runoff	176	Land Segment 1	–	–	1	1	40	12	31	74	35
		179	Land Segment 2	–	–	1	1	40	12	31	74	35
		182	Land Segment 3	–	–	1	1	40	12	31	74	35
		185	Land Segment 4	–	–	1	1	40	12	31	74	35
		188	Land Segment 5	–	–	1	1	40	12	31	74	35
		191	Land Segment 6	–	–	1	1	40	12	31	74	35
		194	Land Segment 7	–	–	1	1	40	12	31	74	35
		197	Land Segment 8	–	–	1	1	40	12	31	74	35
		200	Land Segment 9	–	–	1	1	40	12	31	74	35
		203	Land Segment 10	–	–	1	1	40	12	31	74	35
		206	Land Segment 11	–	–	1	1	40	12	31	74	35
		209	Land Segment 12	–	–	1	1	40	12	31	74	35
		212	Land Segment 13	–	–	1	1	40	12	31	74	35
	Subsurface Runoff	177	Land Segment 1	–	–	1	1	40	12	31	74	35
		180	Land Segment 2	–	–	1	1	40	12	31	74	35
		183	Land Segment 3	–	–	1	1	40	12	31	74	35
		186	Land Segment 4	–	–	1	1	40	12	31	74	35
		189	Land Segment 5	–	–	1	1	40	12	31	74	35
		192	Land Segment 6	–	–	1	1	40	12	31	74	35
		195	Land Segment 7	–	–	1	1	40	12	31	74	35
		198	Land Segment 8	–	–	1	1	40	12	31	74	35
		201	Land Segment 9	–	–	1	1	40	12	31	74	35
		204	Land Segment 10	–	–	1	1	40	12	31	74	35
		207	Land Segment 11	–	–	1	1	40	12	31	74	35
		210	Land Segment 12	–	–	1	1	40	12	31	74	35
		213	Land Segment 13	–	–	1	1	40	12	31	74	35
	Land Parameters	141	–	–	–	–	–	–	–	–	–	–

Table 76 (continued)

Data Category	Data Type	Index Number of Data Set	Geographic Reference of Data: Name	NWS I.D. Number	USGS I.D. Number	Period of Data Set From: Month	Day	Year	To: Month	Day	Year	Duration of Data Set (Years)
Point Loads	Flow	301	Germantown Old Village STP	–	–	1	1	40	12	31	74	35
		321	Germantown County Line STP	–	–	1	1	73	12	31	73	1
		341	Menomonee Falls Pilgrim Road STP	–	–	1	1	40	12	31	74	35
		361	Menomonee Falls Lilly Road STP	–	–	1	1	40	12	31	74	35
		381	Butler By-Pass	–	–	1	1	40	12	31	74	35
	Water Temperature	302	Germantown Old Village STP	–	–	1	1	40	12	31	74	35
		322	Germantown County Line STP	–	–	1	1	73	12	31	73	1
		342	Menomonee Falls Pilgrim Road STP	–	–	1	1	40	12	31	74	35
		362	Menomonee Falls Lilly Road STP	–	–	1	1	40	12	31	74	35
		382	Butler By-Pass	–	–	1	1	40	12	31	74	35
	Dissolved Oxygen	303	Germantown Old Village STP	–	–	1	1	40	12	31	74	35
		323	Germantown County Line STP	–	–	1	1	73	12	31	73	1
		343	Menomonee Falls Pilgrim Road STP	–	–	1	1	40	12	31	74	35
		363	Menomonee Falls Lilly Road STP	–	–	1	1	40	12	31	74	35
		383	Butler By-Pass	–	–	1	1	40	12	31	74	35
	Fecal Coliform	304	Germantown Old Village STP	–	–	1	1	40	12	31	74	35
		324	Germantown County Line STP	–	–	1	1	73	12	31	73	1
		344	Menomonee Falls Pilgrim Road STP	–	–	1	1	40	12	31	74	35
		364	Menomonee Falls Lilly Road STP	–	–	1	1	40	12	31	74	35
		384	Butler By-Pass	–	–	1	1	40	12	31	74	35
	Total Dissolved Solids	305	Germantown Old Village STP	–	–	1	1	40	1	1	74	35
		325	Germantown County Line STP	–	–	1	1	73	12	31	73	1
		345	Menomonee Falls Pilgrim Road STP	–	–	1	1	40	12	31	74	35
		365	Menomonee Falls Lilly Road STP	–	–	1	1	40	12	31	74	35
		385	Butler By-Pass	–	–	1	1	40	12	31	74	35
	NH_3-N	307	Germantown Old Village STP	–	–	1	1	40	12	31	74	35
		327	Germantown County Line STP	–	–	1	1	73	12	31	73	1
		347	Menomonee Falls Pilgrim Road STP	–	–	1	1	40	12	31	74	35
		367	Menomonee Falls Lilly Road STP	–	–	1	1	40	12	31	74	35
		387	Butler By-Pass	–	–	1	1	40	12	31	74	35
	NO_2-N	308	Germantown Old Village STP	–	–	1	1	40	12	31	74	35
		328	Germantown County Line STP	–	–	1	1	73	12	31	73	1
		348	Menomonee Falls Pilgrim Road STP	–	–	1	1	40	12	31	74	35
		368	Menomonee Falls Lilly Road STP	–	–	1	1	40	12	31	74	35
		388	Butler By-Pass	–	–	1	1	40	12	31	74	35

Table 76 (continued)

Data Category	Data Type	Index Number of Data Set	Geographic Reference of Data: Name	NWS I.D. Number	USGS I.D. Number	Period of Data Set From: Month	Day	Year	To: Month	Day	Year	Duration of Data Set (Years)
Point Loads (continued)	PO_4-P	309	Germantown Old Village STP	--	–	1	1	40	12	31	74	35
		329	Germantown County Line STP	--	–	1	1	73	12	31	73	1
		349	Menomonee Falls Pilgrim Road STP	--	–	1	1	40	12	31	74	35
		369	Menomonee Falls Lilly Road STP	--	–	1	1	40	12	31	74	35
		389	Butler By-Pass	–	–	1	1	40	12	31	74	35
	NO_3-N	310	Germantown Old Village STP	--	–	1	1	40	12	31	74	35
		330	Germantown County Line STP	–	–	1	1	73	12	31	73	35
		350	Menomonee Falls Pilgrim Road STP	–	–	1	1	40	12	31	74	35
		370	Menomonee Falls Lilly Road STP	--	–	1	1	40	12	31	74	35
		390	Butler By-Pass	–	–	1	1	40	12	31	74	35
	$CBOD_u$	311	Germantown Old Village STP	--	–	1	1	40	12	31	74	35
		331	Germantown County Line STP	–	–	1	1	73	12	31	73	1
		351	Menomonee Falls Pilgrim Road STP	–	--	1	1	40	12	31	74	35
		371	Menomonee Falls Lilly Road STP	--	–	1	1	40	12	31	74	35
		391	Butler By-Pass	–	–	1	1	40	12	31	74	35

Source: SEWRPC.

to operate the five submodels. Of equal importance are calibration data which, although not needed to operate the model, are necessary for the calibration—that is the validation—of the model. These data, which are derived strictly from field measurements, include "real world" streamflow, river stage, and water quality data. Since calibration data represent the actual historic response of the watershed to a variety of hydro-meteorological events and conditions, such data may be compared to the simulated response of the watershed and the model thereby calibrated and validated.

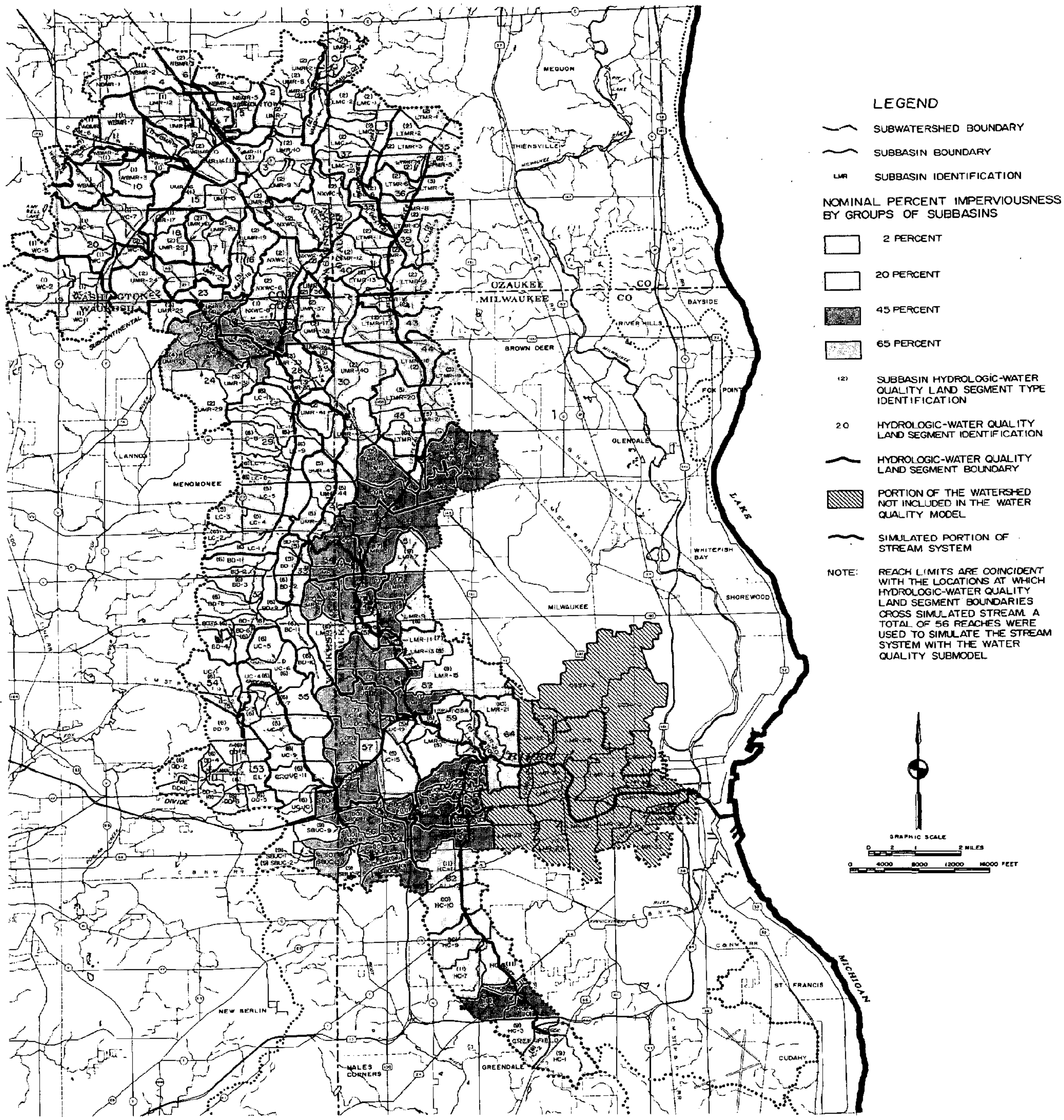
Streamflow Data: The principal source of historic streamflow information in the watershed are the daily streamflow measurements made by the U. S. Geological Survey (USGS) since October 1, 1961, at the wire-weight gage located at the N. 70th Street crossing of the Menomonee River. This streamflow information was supplemented with discharge data from three partial record gaging stations—a crest stage gage, a low flow gage, and a combination crest stage-low flow gage—also maintained by the USGS. A detailed discussion of these four stream gaging stations and an analysis of the data obtained from them are presented in Chapter V of this volume. Daily flow data for the Menomonee River gaging station were coded and placed on a magnetic disc file for ready recall and comparison—by computer-generated tables and graphs—to simulated daily streamflows at that location. Because of the discontinuous nature of the streamflow data from the three partial record gages, comparisons between that recorded information and simulated flows were performed manually.

Flood Stage Data: As described in Chapter V of this volume, crest or staff gages are maintained on the watershed stream system by the Milwaukee-Metropolitan Sewerage Commissions, the City of Milwaukee, and the Village of Menomonee Falls. Information on historic high water levels obtained from this network of gages, supplemented with information provided by public officials, consulting engineers, private citizens, and the staff of the Regional Planning Commission, were plotted on profiles of the stream system and used to check the validity of simulated flood stage profiles. Additional information on the source and characteristics of historic flood stage information is presented in Chapter VI of this volume.

Water Quality Data: The principal source of historic water quality data is the three 24-hour watershedwide field surveys carried out, as described in Chapter VII of this volume, under the Menomonee River watershed planning program. In each of these surveys, streamflow measurements were made at five locations on the stream system, while physical, chemical, and biological quality indicators were measured at 17 instream sampling sites. In addition, the surveys involved the conduct of water

Map 80

REPRESENTATION OF THE MENOMONEE RIVER WATERSHED FOR WATER QUALITY SIMULATION: 1975



For purposes of water quality modeling, the watershed land surface was partitioned into 56 hydrologic-water quality land segments and the watershed stream system was subdivided into 56 reaches.The hydrologic-water quality land segments were the basis for simulating the transport of potential pollutants from the land surface to the stream system via direct runoff or groundwater flow. Each stream reach, as represented by a set of parameters, was used to simulate the accumulation of potential pollutants in the channel system and the resulting instream biochemical and advection processes.

Source: SEWRPC.

quality analyses on the effluent from five municipal sewage treatment plants and two industrial facilities. Twenty-four hour synoptic water quality surveys were conducted during a mild spring runoff event on April 4 and 5, 1973, and during summer low flow periods on July 18 and 19, 1973, and on August 6 and 7, 1974.

MODEL CALIBRATION

Need for and Nature of Model Calibration

Many of the algorithms contained in the model are mathematical approximations of complex natural phenomena. Therefore, before the model could be used to reliably simulate streamflow behavior and water quality conditions under alternative hypothetical watershed development conditions, it was necessary to calibrate the model, that is, to compare simulation model results with factual historic data and, if a significant difference was found, to make parameter adjustments so as to adjust—or calibrate—the model to the specific natural and man-made features of the watershed.[28] While the model is general in that it is applicable to a wide range of geographic and climatic conditions, its successful application to any given water resource system—such as the Menomonee River watershed—very much depends on the calibration process in which pertinent data on the natural resource and man-made features of the watershed are used to adapt the model to the local conditions. A schematic representation of the model calibration process as used in the Menomonee River watershed planning program is shown in Figure 70.

Once the watershed simulation model is calibrated for a particular water resource system, the basic premise of the simulation process is that the model will respond accurately to a variety of model inputs representing hypothetical watershed conditions—such as land use changes and channel modifications—and thereby provide a powerful analytic tool in the watershed planning process.

Of the three types of validation data available—streamflow data, flood stage data, and water quality data—for southeastern Wisconsin in general and the Menomonee River watershed in particular, streamflow data are the most available, flood stage data are less available and water quality data are least available. There is a considerable and generally adequate data base available, therefore, for calibration of the Hydrologic Submodel, Hydraulic Submodel 1, and Hydraulic Submodel 2 of the overall model. A less adequate data base is available for the calibration of the Water Quality Submodel. In a strict sense, no data are available for the systematic, watershedwide calibration of the Flood Economics Submodel. This is not a serious limitation of that Submodel, however, since these relationships are based on recognized stage-damage relationships for various structure types. Furthermore, scattered and diverse information on the number of structures affected and monetary losses incurred were used to verify the reasonableness of results obtained through application of the Flood Economics Submodel.[29]

Successful calibration and testing of the first three submodels are of utmost importance because output from those submodels has direct bearing on the test and evaluation of the floodland management elements of the watershed plan and also because the validity of results from the other two submodels—the Water Quality Submodel and the Flood Economics Submodel—are determined, in part, by the quality of the output of the first three submodels.

Initial Calibration of the Hydrologic Submodel and Hydraulic Submodel 1 on Homogeneous Subwatersheds

The Menomonee River watershed is heterogeneous with respect to hydrologic soil groups, ground slope, and land use-cover. As indicated in Table 75, for example, the watershed contains five different combinations of soil group and land use-cover. Inasmuch as the single daily streamflow gaging station in the watershed—the U. S. Geological Survey Gage located at the N. 70th Street crossing of the Menomonee River—receives runoff from land containing five different soil group and land use-cover complexes, it was not feasible to initiate the calibration process directly on the Menomonee River watershed. Sound practice required that the initial calibration of hydrologic-hydraulic portions of a simulation model should be conducted on watersheds or subwatersheds that are essentially homogeneous with respect to those characteristics that are the primary determinants of the hydrologic-hydraulic response. By following this approach, only one or, at most, two sets of land and channel parameters need be dealt with during each calibration run. Parameter values determined by calibration runs on the homogeneous basins may then be applied to similar portions of the heterogeneous watershed prior to conducting calibration runs on the latter.

Selection of Subwatersheds: The Region and surrounding areas accordingly were examined for the purpose of identifying several watersheds or subwatersheds having a minimum of about five years of streamflow records and exhibiting soil group and land-use cover combinations similar to one of the five combinations present in the Menomonee River watershed. An additional criterion was that the test basins be relatively close to one or more of the National Weather Service stations used to develop the Menomonee River watershed simulation model, thereby minimizing the amount of additional meteorological data base development that would be required.

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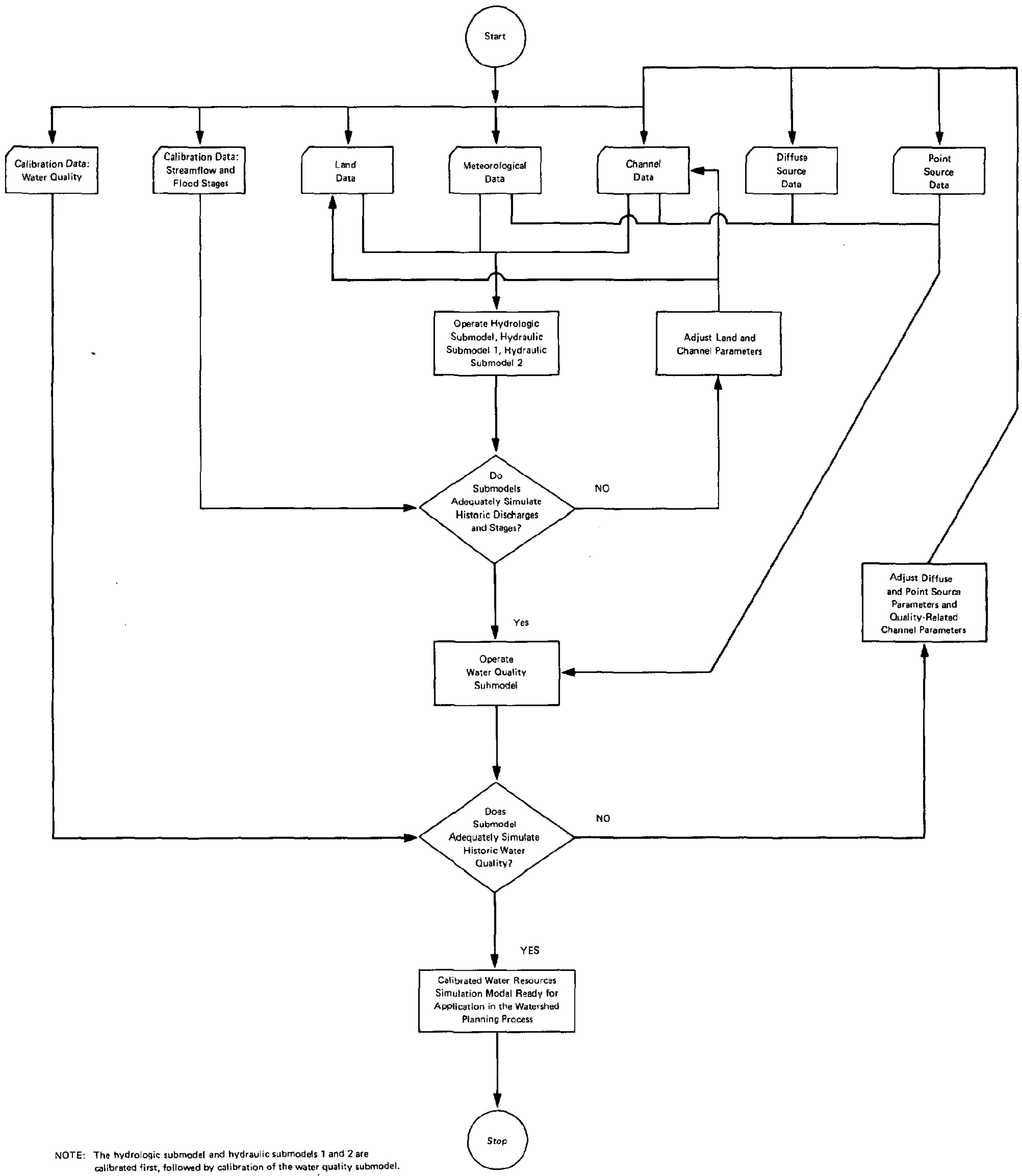
[28] *In some simulation model applications, parameter adjustments are not sufficient and it is necessary to improve the algorithms in the model. This problem did not arise in the application of the model to the Menomonee River watershed.*

[29] *See SEWRPC Staff Memorandum to the Menomonee River Watershed Committee entitled: "Flood Damage Computation Procedures in the Menomonee River Watershed," February 18, 1976, 22 pp.*

Figure 70

THE WATER RESOURCES SIMULATION MODEL CALIBRATION PROCESS



NOTE: The hydrologic submodel and hydraulic submodels 1 and 2 are calibrated first, followed by calibration of the water quality submodel.

Source: SEWRPC.

Three test areas were identified: the 24.8-square-mile Oak Creek subwatershed in Milwaukee County, the 57.9-square-mile Root River Canal subwatershed located principally in Racine County, and the 49.6-square-mile East Branch of the Milwaukee River subwatershed located in Fond du Lac County. The Oak Creek subwatershed is overlain by primarily hydrologic group C soils; it exhibits flat to gently sloping topography; the subwatershed is about two-thirds rural and one-third urban; and 10 years of streamflow data are available for calibration purposes. Moreover, an added advantage of this subwatershed is that it lies very close to the Milwaukee National Weather Service station at Mitchell Field, thereby permiting direct use of the hourly precipitation data set for that station. The Root River Canal Subwatershed is covered by hydrologic group C and D soils; the topography is flat to gently sloping; the subwatershed is almost entirely rural; and 10 years of streamflow data are available. The East Branch subwatershed is overlain by primarily hydrologic group B soils; it exhibits gently rolling topography; it is essentially all rural; and more than five years of streamflow data are available.[30]

[30] *The availability of a continuous record of streamflow data for the three subwatersheds was a key element in the model calibration process. The three streamflow gaging stations were established and are maintained as a cooperative effort among various local governmental units and agencies, the U. S. Geological Survey, and the Commission. The Oak Creek subwatershed gage is cooperatively maintained by the USGS, the Metropolitan Sewerage Commission of Milwaukee County, and the Commission. The Root River Canal subwatershed gage is cooperatively maintained, as recommended in the Comprehensive Plan for the Root River Watershed, by the USGS, the Metropolitan Sewerage Commission of Milwaukee County, and the Commission. The East Branch subwatershed gage is cooperatively maintained, as recommended in the Comprehensive Plan for the Milwaukee River Watershed, by the USGS, the Fond du Lac County Board, and the Commission.*

Selected information on the three subwatersheds, is set forth in Table 77. As shown in the table, the combinations of hydrologic soil group and land use-cover present in the three subwatersheds represent four of the five different combinations present in the Menomonee River watershed. Therefore, the three test subwatersheds encompass almost the full spectrum of land conditions that exist within the Menomonee River watershed and provide a sound basis for initial calibration efforts.

Oak Creek Subwatershed: The calibration process was conducted first on the Oak Creek subwatershed. Meteorological, land, and channel data sets were prepared in accordance with the data base development procedures described earlier in this chapter. The Hydrologic Submodel and Hydraulic Submodel 1 were operated for the approximately 11 year period from January 1963 through September 1973 using the iterative calibration process shown schematically in Figure 70 until an acceptable agreement was obtained between historic and simulated discharges at the gaging station. The actual calibration interval was the nine-year period from January 1965 through September 1973 with the two-year period immediately prior to this being used for model initialization and start-up purposes.

The results obtained during the calibration process for the gaging station are presented below by comparing recorded and simulated annual runoff volumes, simulated and recorded monthly runoff volumes, simulated and recorded hydrographs for major runoff events, and discharge-frequency relationships based on recorded and simulated annual instantaneous peaks:

- Figure 71 presents a graphic comparison of recorded and simulated annual runoff volumes. Simulated annual runoff volumes, on a calendar year basis, ranged from 11 percent below to 30 percent above recorded values. The absolute average percent difference between recorded and simulated annual runoff volumes was about 9 percent. The simulated cumulative annual runoff

Table 77

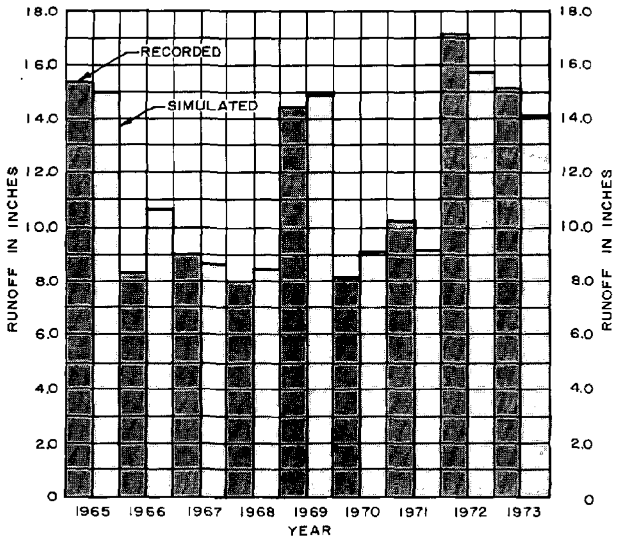
SELECTED INFORMATION ON SUBWATERSHEDS USED IN THE INITIAL VALIDATION OF THE HYDROLOGIC SUBMODEL AND HYDRAULIC SUBMODEL 1

Subwatershed		USGS Stream Gaging Station					Area Tributary To Gage (square miles)	Hydrologic Soil Group		Ground Slope		Land Use and Cover		Nearest National Weather Service Station(s)		Comment
				Period of Record Available												
Name	County	Number	Type	From	To	Duration Years		Dominant Group(s)	Percent of Area Covered	0-4 Percent	Over 4 Percent	Rural (Percent)	Urban (Percent)	Daily Data	Hourly Data	
Oak Creek	Milwaukee	04-0872.04	Continuous Recorder	10/63	9/73	10	24.8	C	80	X	--	67	33	Milwaukee	Milwaukee	Urban portion similar to land segment types 3, 4, 6, 7, 9, and 10 in the Menomonee River watershed. Rural portion similar to land segment types 2 and 5 in the Menomonee River watershed
Root River Canal	Racine, Kenosha	4-0872.33	Continuous Recorder	10/63	9/73	10	57.9	C D	61 21	X	--	95	5	Union Grove	Milwaukee	Similar to land segment types 2 and 5 in the Menomonee River watershed
East Branch of the Milwaukee River	Fond du Lac	4-0862.00	Continuous Recorder	4/68	9/73	5.5	49.6	B	72	X	--	98	2	West Bend	Hartford, Milwaukee	Similar to land segment type 1 in the Menomonee River watershed

Source: SEWRPC.

Figure 71

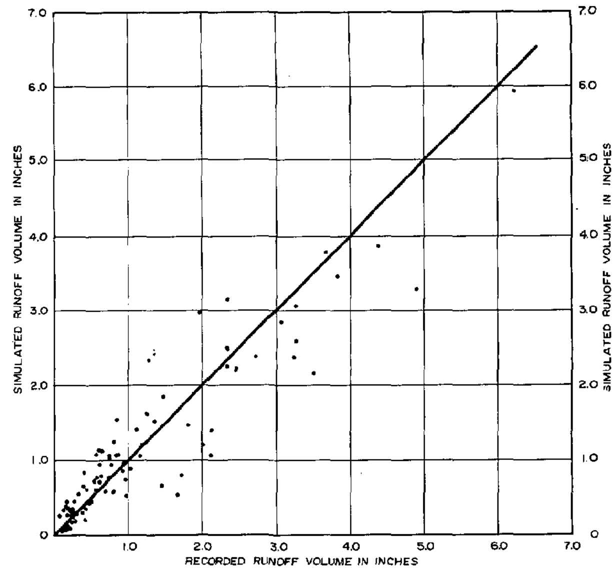
RECORDED AND SIMULATED ANNUAL RUNOFF VOLUMES FOR THE OAK CREEK AT THE 15TH AVENUE GAGE: JANUARY 1, 1965, TO SEPTEMBER 30, 1973



Source: SEWRPC.

Figure 72

RECORDED AND SIMULATED MONTHLY RUNOFF VOLUMES FOR THE OAK CREEK AT THE 15TH AVENUE GAGE: JANUARY 1, 1965, TO SEPTEMBER 30, 1973



Source: SEWRPC.

volume for the nine-year calibration period was 105.7 inches, or 0.2 percent less than the cumulative recorded volume for that same period.

- Recorded and simulated monthly runoff volumes are compared in Figure 72. Monthly runoff data are seen to be oriented about a 45-degree line indicating a tendency to exhibit the desired one-to-one correlation between simulated and recorded monthly runoff volumes.

- Recorded and simulated hydrographs for four runoff events drawn from various times of the year are shown in Figure 73. These hydrographs were selected so as to represent the full range of correlation types obtained between recorded and simulated hydrographs. The simulated and recorded hydrographs for a variety of rainfall and rainfall-snowmelt events generally exhibited close agreement. Some inconsistencies were observed for certain winter and spring events (such as for the first of the two major peaks associated with the April 1973 event as shown in Figure 73) when precipitation was simulated as rainfall but actually occurred as snowfall, or vice versa. In some instances, the lack of a good correlation between recorded and simulated hydrographs—for example, significant differences in runoff volume and magnitude of peak discharge (such as for September 1972 event as shown in Figure 73) or in time of peak discharge—is thought to be attributable to the causative precipitation event having a temporal distribution over the watershed that was different from that at the nearest monitoring location—the Mitchell Field National Weather Service station—which was used as model input. Such differences also may be attributable to spatial variations in the amount of rainfall occurring over the watershed; that is, even though the precipitation observation station used to provide input data is located on the edge of the Oak Creek watershed and even though the watershed is small—24.8 square miles—it is possible for portions of the basin to receive precipitation amounts during brief, but intense, rainfall events that are significantly different from those recorded at the observation station.

- Recorded and simulated annual instantaneous peak discharges for the nine year calibration period are compared in Figure 74 in the form of discharge-frequency relationships developed with the log-Pearson Type III analytic technique. Inasmuch as only nine years of data were used for development of the two discharge-frequency relationships, the relationships cannot be expected to be reliable for extreme flood events such as those having a recurrence interval of 100 years or more.[31] Using 10-year recurrence interval flood discharges for comparison purposes, the 10-year recurrence interval discharge based on nine years of simulated flood flows is about 18 percent above the 10-year recurrence interval discharge based on nine years of historic flood events.

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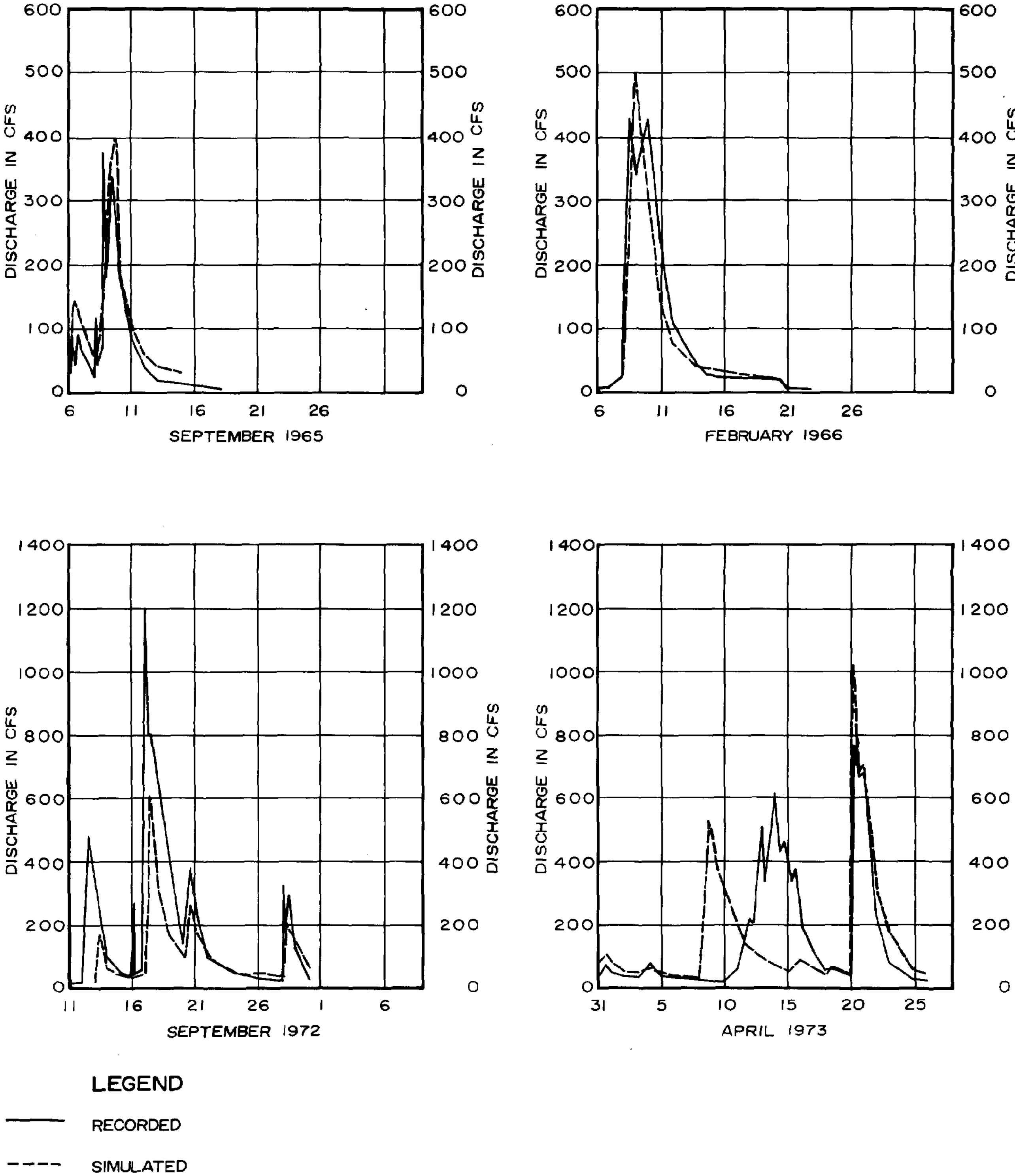
[31] *Refer to Chapter V, Volume 1, of this report for a discussion of the relationship between the length of streamflow record and the reliability of the discharge-frequency relationship based on that record.*

Figure 73

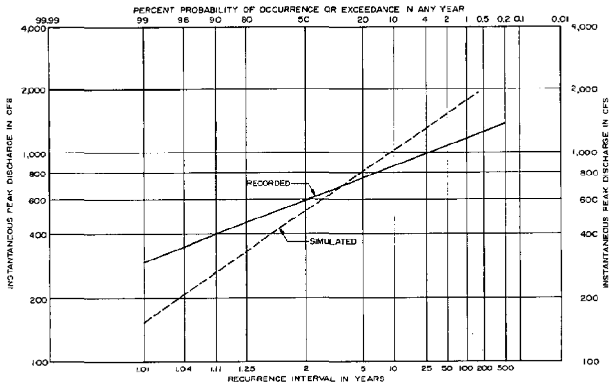
RECORDED AND SIMULATED HYDROGRAPHS FOR THE OAK CREEK AT THE 15TH AVENUE GAGE SELECTED DATES, SEPTEMBER 1965 TO APRIL 1973



Source: SEWRPC.

Figure 74

RECORDED AND SIMULATED DISCHARGE-FREQUENCY RELATIONSHIPS FOR THE OAK CREEK AT THE 15TH AVENUE GAGE: WATER YEARS 1965-1973



Source: SEWRPC.

Root River Canal and East Branch of the Milwaukee River Subwatersheds: After completion of the Oak Creek subwatershed calibration, meteorological, channel, and land data sets were developed for the rural Root River Canal and East Branch of the Milwaukee River subwatersheds in accordance with the data base development procedures described earlier in this chapter. Numerical values selected for Root River Canal subwatershed land parameters were strongly influenced by the parameter values previously established for the similar rural portion of the Oak Creek subwatershed.

The Hydrologic Submodel and Hydraulic Submodel 1 were operated on the Root River Canal subwatershed for the 11-year period from October 1962 through September 1973 using the iterative calibration process shown schematically in Figure 70 until an acceptable agreement was obtained between historic and simulated discharges at the gaging station. The actual calibration interval was the 10-year period from October 1963 through September 1973 in that the one-year period immediately prior to this was used for model initialization and start-up purposes. As was the case with the Oak Creek subwatershed, the calibration process included a comparison of recorded and simulated annual and monthly runoffs as well as runoff event hydrographs and discharge-frequency relationships so as to assure that all hydrologic-hydraulic processes were adequately represented.[32]

The Hydrologic Submodel was operated on the East Branch of the Milwaukee River subwatershed for the approximately eight-year period from January 1965 through December 1972 using the iterative calibration process shown schematically in Figure 70 until an acceptable agreement was obtained between historic and simulated annual and seasonal discharges at the gaging station. The actual calibration interval was the 4.7-year period from May 1968 through December 1972; the 3.3-year period immediately prior to this was used for model initialization and start-up purposes. Inasmuch as the principal purpose at this stage of the calibration process was to determine optimum values of land parameters for the land use-soil type-slope combination represented by the East Branch of the Milwaukee River subwatershed, only the Hydrologic Submodel was applied, thus saving data preparation and run costs attendant to use of Hydraulic Submodel 1.

Concluding Statement—Initial Calibration: The intial calibration process on the three test subwatersheds indicated that the combination of the Hydrologic Submodel and Hydraulic Submodel 1 could effectively simulate the hydrologic-hydraulic response of a basin to a wide variety of meteorologic inputs. A close correlation was achieved between simulated and recorded annual and monthly runoff volumes, simulated and recorded hydrographs for major runoff events, and discharge-frequency relationships based on recorded and simulated flood flows. With respect to the Menomonee River watershed, the initial calibration process conducted on three subwatersheds yielded two key results: it demonstrated the capability of the hydrologic-hydraulic portions of the Water Resource Simulation Model, and it provided numerical values for up to 28 land parameters for use in the simulation modeling of the Menomonee River watershed.

Menomonee River Watershed Calibration

After completing calibration of the Hydrologic Submodel and Hydraulic Submodel 1 on the three homogeneous subwatersheds, the second and final stage of the calibration procedure was initiated. That stage consisted of the calibration of the Hydrologic Submodel, Hydraulic Submodels 1 and 2, and the Water Quality Submodel on the heterogeneous Menomonee River watershed.

Hydrologic Submodel and Hydraulic Submodel 1: Meteorological data sets, land data sets for land segment types, and channel data sets for stream reaches were prepared using the procedures described earlier in this chapter. The choice of numerical values for the 28 parameters in each of the land data sets was strongly influenced by the parameter values previously established for the three homogeneous subwatersheds. This was feasible since, as noted above, four of the five different combinations of soil type and land use-cover present in the Menomonee River watershed are represented in the three test subwatersheds.

Land use data presented in Chapter III of this volume indicate that urban land use in the watershed increased from 63.6 square miles in 1963 to 72.7 square miles in 1970—a 14 percent increase. The historic urban growth pattern depicted on Map 9 indicates that the 9.1 square miles of land undergoing conversion from rural to urban land use during that seven-year period are widely scattered throughout the upper two-thirds of the watershed.

[32] *Information on calibration results, similar to that included in this report for the Oak Creek subwatershed, is available in Commission files for the Root River Canal and East Branch of the Milwaukee River subwatersheds.*

Because the 1963 to 1970 rural-to-urban land use conversion was small and the affected areas were widely scattered, it was generally not necessary to incorporate that land use change into the 1961-1973 model calibration period. Exceptions include an area near the upstream end of the Honey Creek subwatershed which was modeled as being converted from low- to medium-density residential development in 1974 and an area along the Menomonee River near Capitol Drive and the Waukesha-Milwaukee County line which was also modeled as being converted from low- to medium-density residential in 1974.

As discussed in Chapter V of this volume and as shown on Maps 39 and 40, major channelization work has been carried out on 15.4 miles of the watershed stream system and, in addition, 2.6 miles of the stream system have been placed in conduit. Some of the major stream system modifications occurred during the 1961-1973 calibration period and had the potential to alter the temporal distribution of runoff from the watershed. The chronological order of completion and the linear extent of 10.2 miles of channel modifications most likely to affect the distribution of watershed runoff is set forth in Table 78. In order to properly reflect the channel system changes that occurred during the 12-year calibration period, three channel data sets were used for the modified reaches—one set for the period from 1961 through 1969, one set for the period from 1970 through 1972, and one set for the 1973-1974 period.

In order to make maximum use of the historic streamflow records in the Menomonee River watershed, the Hydrologic Submodel and Hydraulic Submodel 1 were first calibrated against two of the U. S. Geological Survey partial record gages in the basin, one located on Honey Creek at S. 68th Street in the City of Milwaukee and the other on the Little Menomonee River at Donges Bay Road in the City of Mequon. The 3.34-square-mile area tributary to the Honey Creek gage consists entirely of low- and medium-density urban land use over hydrologic soil group C soils and at a slope of less than 4 percent. The soils, slope, and land use cover for this area are similar to those found in the urban portion of the Oak Creek subwatershed; therefore, land parameters similar to those obtained as a result of the Oak Creek calibration were applied to the area tributary to the Honey Creek partial record gage. The 7.96-square-mile area tributary to the Little Menomonee River gage consists of rural land use with primarily hydrologic soil group C soils and slopes of less than 4 percent. This soil, slope, and land use-cover combination is similar to the rural portion of the Oak Creek subwatershed and most of the Root River Canal subwatershed, and, therefore, land parameters

Table 78

SELECTED INFORMATION ON MAJOR CHANNEL MODIFICATIONS ON UNDERWOOD CREEK, THE SOUTH BRANCH OF UNDERWOOD CREEK, AND HONEY CREEK IN THE MENOMONEE RIVER WATERSHED

Period During Which Major Channel Modifications Were Completed	Underwood Creek[a]				South Branch of Underwood Creek				Honey Creek				Total Length By Time Period (Miles)
	From (River Mile)	To (River Mile)	Length (Miles)	Type	From (River Mile)	To (River Mile)	Length (Miles)	Type	From (River Mile)	To (River Mile)	Length (Miles)	Type	
1961-1969	0.00	1.54	1.54	Open Channel	--	--	--	--	0.91 1.99 5.96	1.99 4.32 6.54	1.08 2.33 0.58	Open Channel Conduit Open Channel	5.53
1970-1972	--	--	--	--	0.00	1.08	1.08	Open Channel	4.32	5.96	1.64	Open Channel	2.72
1973-1974	1.54	2.54	1.00	Open Channel	--	--	--	--	6.54	7.53	0.99	Open Channel	1.99
Total Length By Stream	--	--	2.54	--	--	--	1.08	--	--	--	6.62	--	10.24

[a] *Includes only that portion of Underwood Creek downstream of the confluence with the South Branch of Underwood Creek. Although some major channel modifications exist on Underwood Creek upstream of the confluence with the South Branch, the time of occurrence of these modifications is not significant for model calibration purposes.*

Source: SEWRPC.

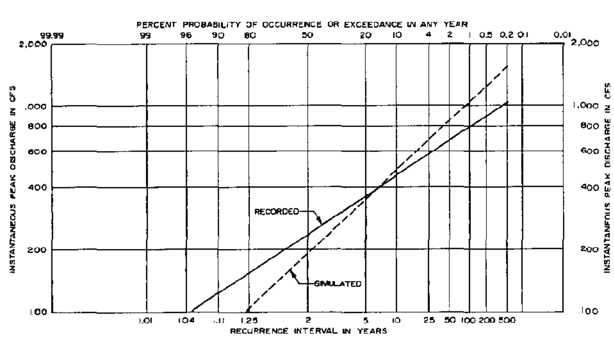
similar to those developed by the Oak Creek and Root River Canal calibrations were used to characterize the area tributary to the Little Menomonee River gage.

The Hydrologic Submodel and Hydraulic Submodel 1 were operated for the 15-year period from October 1958 through September 1973 on the area tributary to the Honey Creek gage and for the 16-year period from October 1957 through September 1973 on the area tributary to the Little Menomonee River gage using the iterative calibration process shown in Figure 70. Inasmuch as partial record gages provide only annual instantaneous peak flows, only the simulated annual instantaneous peak flows could be compared to the historic record. This comparison is presented in Figures 75 and 76 in the form of two discharge-frequency curves for each station—one based on the simulation modeling results and one based on the historic record. Since the Honey Creek discharge-frequency relationship is based on only 15 years of flow data and the Little Menomonee River discharge-frequency relationship is based on only 16 years of flow data, the relationships cannot be expected to be very reliable for an extreme flood event such as that having a recurrence interval of 100-years or more. Using 20-year recurrence interval flood discharges for comparison, the 20-year discharge for the Honey Creek gaging station based on simulated flood flows was found to be about 15 percent above the 20-year discharge based on recorded flood flows. The 20-year discharge for the Little Menomonee River gaging station based on simulated flood flows was found to be about 6 percent less than the 20-year discharge based on recorded flood flows.

After successfully calibrating the Hydrologic Submodel and Hydraulic Submodel 1 against the two partial record gages, these two submodels were operated for the 123-square-mile area tributary to the U. S. Geological Survey wire-weight gage on the Menomonee River located at N. 70th Street in the City of Wauwatosa. The calibration interval for these runs, which encompassed essentially the entire watershed, was the 12-year period extending from October 1961 through September 1973.

Figure 75

RECORDED AND SIMULATED HISTORIC DISCHARGE-FREQUENCY RELATIONSHIPS FOR HONEY CREEK AT S. 68TH STREET: WATER YEARS 1959-1973



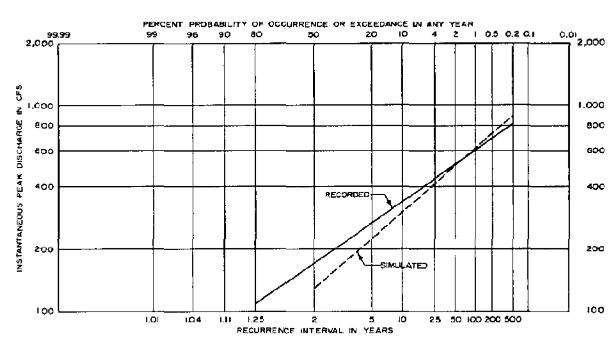
Source: SEWRPC.

The results obtained in the calibration process for the Menomonee River gaging station are presented below by comparing recorded and simulated annual runoff volumes, recorded and simulated monthly runoff volumes, recorded and simulated hydrographs from major runoff events, recorded and simulated annual instantaneous peak flows, and discharge-frequency relationships based on recorded and simulated annual instantaneous peaks.

- Figure 77 presents a graphic comparison of recorded and simulated annual runoff volumes. Simulated annual runoff volumes, on a calendar year basis, range from 15 percent below to 34 percent above recorded values; the absolute average percent difference between recorded and simulated annual runoff volumes was about 11 percent. The simulated cumulative annual runoff volume for the period January 1, 1963, through September 30, 1973, was 101.0 inches, or 0.5 percent more than the cumulative recorded runoff volume for that same period.
- Recorded and simulated monthly runoff volumes are compared in Figure 78. Monthly runoff data are seen to be grouped about a 45-degree line, indicating a tendency to exhibit the desired one-to-one correlation between simulated and recorded monthly runoff volumes.
- Recorded and simulated hydrographs for four selected runoff events drawn from various times of the year are shown in Figure 79. The simulated and recorded hydrographs for a variety of rainfall and rainfall and rainfall-snowmelt events generally exhibited close agreement. The observed differences between recorded and simulated hydrographs are probably explained by the same factors discussed above for the Oak Creek subwatershed calibration.
- Recorded and simulated annual instantaneous peak discharges for the 12-year calibration

Figure 76

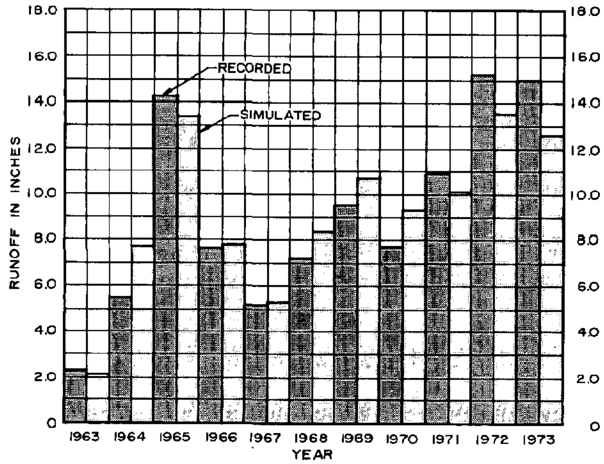
RECORDED AND SIMULATED HISTORIC DISCHARGE-FREQUENCY RELATIONSHIPS FOR LITTLE MENOMONEE RIVER AT DONGES BAY ROAD WATER YEARS 1958-1973



Source: SEWRPC.

Figure 77

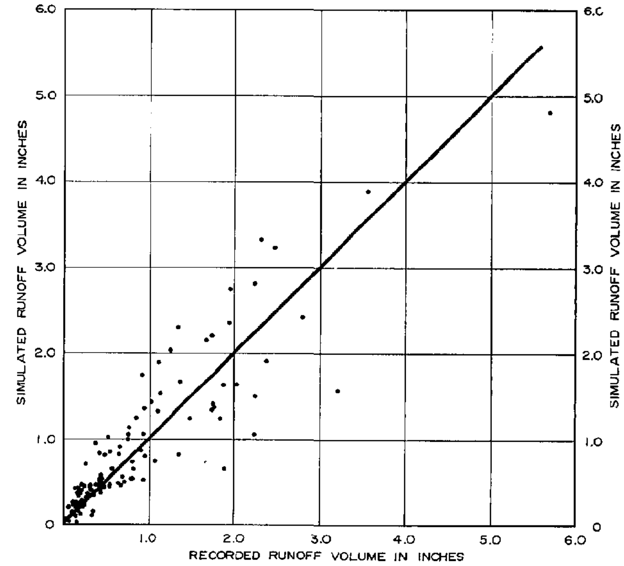
RECORDED AND SIMULATED ANNUAL RUNOFF VOLUMES FOR THE MENOMONEE RIVER AT THE WAUWATOSA GAGE JANUARY 1, 1963, TO SEPTEMBER 30, 1973



Source: SEWRPC.

Figure 78

RECORDED AND SIMULATED MONTHLY RUNOFF VOLUMES FOR THE MENOMONEE RIVER AT THE WAUWATOSA GAGE JANUARY 1, 1963, TO SEPTEMBER 30, 1973



Source: SEWRPC.

period are compared in Figure 80 in the form of discharge-frequency relationships developed with the log-Pearson Type III analytic technique. Inasmuch as only 12 years of data are used for development of the two discharge-frequency relationships, the relationships cannot be expected to be reliable for extreme flood events such as those having a recurrence interval of 100 years or more. The simulated and recorded discharge-frequency relationships are seen to be almost coincident over a wide range of flood flows; for example, for two-year through 100-year recurrence interval conditions, the simulated and recorded discharges are within 5 percent of each other.

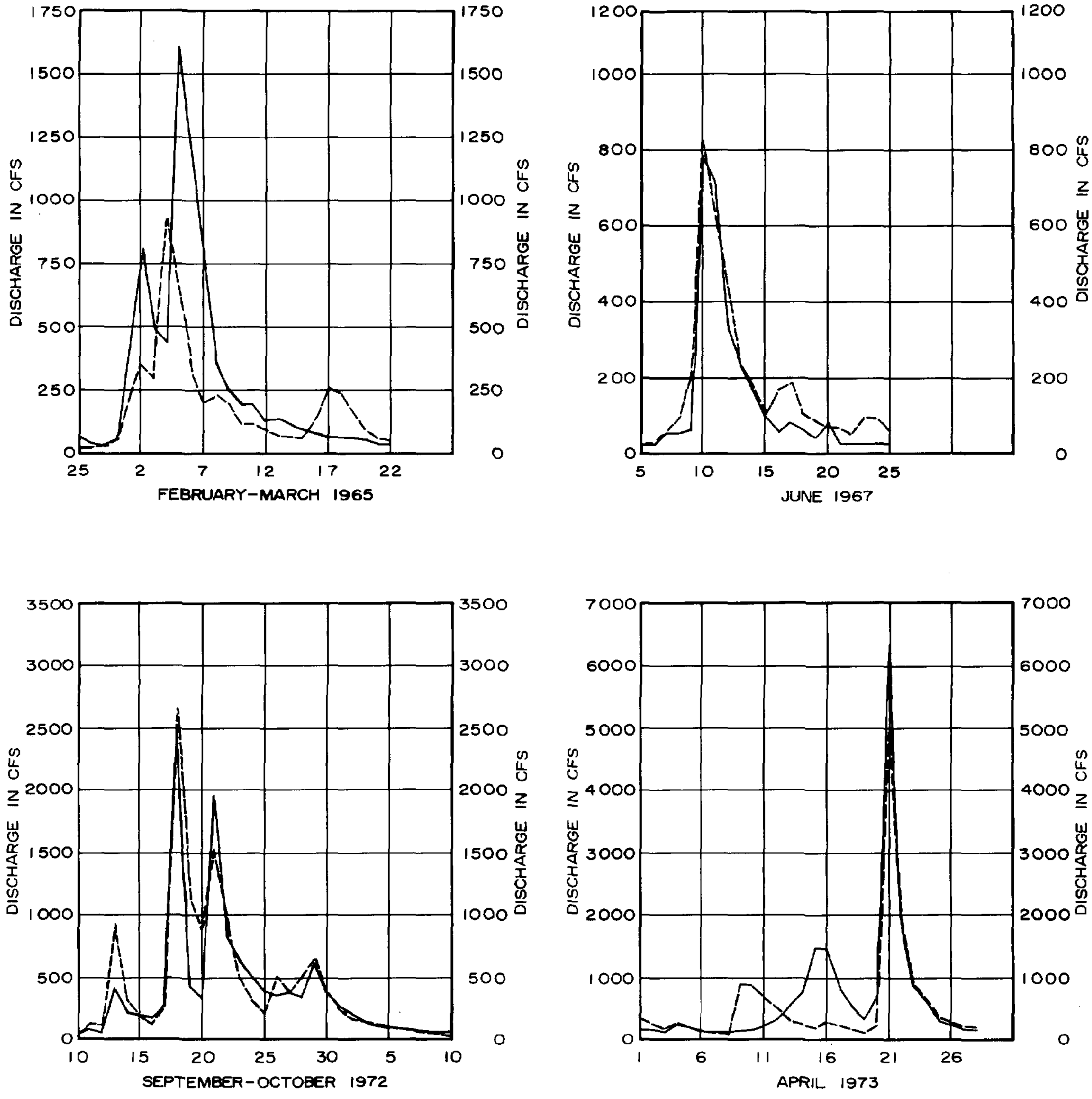
- Figure 81 graphically compares the magnitude of recorded and simulated annual instantaneous peak flows for the 12 water years from October 1, 1961, through September 30, 1973. The plotted annual instantaneous peak flows are generally positioned along a 45-degree line, indicating a strong tendency to exhibit the desired one-to-one relationship.

As discussed earlier in this chapter, operation of the Hydrologic Submodel requires establishing, through measurement and calibration, input data consisting of 28 land parameters. The calibration process, as carried out on subwatersheds outside of the Menomonee River watershed as well as the Menomonee River watershed itself, was particularly valuable in assigning values to the following seven land parameters, each of which was seen to be dependent upon soil type, topographic conditions, land use-cover, and on regional meteorologic characteristics: UZSN, the nominal groundwater storage in the upper soil zones; LZSN, the nominal groundwater storage in the lower soil zones; INFILTRATION, the infiltration rate index; INTERFLOW, the interflow index; RADCON and CONDS-CONV, parameters used to adjust snowmelt equations to field conditions; and TSNOW, air temperature below which precipitation occurs. While these and other parameters may be expected to vary significantly from one part of the United States to another, they tend to exhibit a strong similarity within climatically and physiographically homogeneous areas such as the Southeastern Wisconsin Regional Planning Region. Therefore, calibration runs carried out in conjunction with the Menomonee River watershed planning program are very likely to yield land parameter values that are directly applicable to other parts of the seven-county planning region having similar soil type, topography, and land use-cover characteristics.

Hydraulic Submodel 2: After successful calibration of the Hydrologic Submodel and Hydraulic Submodel 1 in the Menomonee River watershed, annual instantaneous peak dischages from the output of Hydraulic Submodel 1 were used in a log-Pearson Type III analysis to obtain 10-, 50-, 100-, and 500-year recurrence interval discharges throughout the watershed under existing conditions which were in turn used as input to Hydraulic Submodel 2 for the purpose of calibrating that submodel against historic flood stage information. The historic flood inventory described in Chapter VI of this volume resulted in the acquisition and collation of high water data for many streams in the Menomonee River watershed including the main stem of the Menomonee River, the Little Menomonee River, Underwood Creek, and

Figure 79

RECORDED AND SIMULATED HYDROGRAPHS FOR THE MENOMONEE RIVER AT THE WAUWATOSA GAGE
SELECTED DATES, FEBRUARY-MARCH 1965 TO APRIL 1973



LEGEND

——— RECORDED

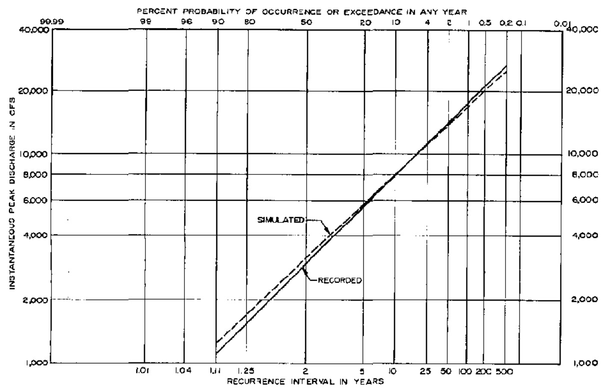
– – – – SIMULATED

NOTE: BASED ON AVERAGE DAILY DISCHARGES

Source: SEWRPC.

Figure 80

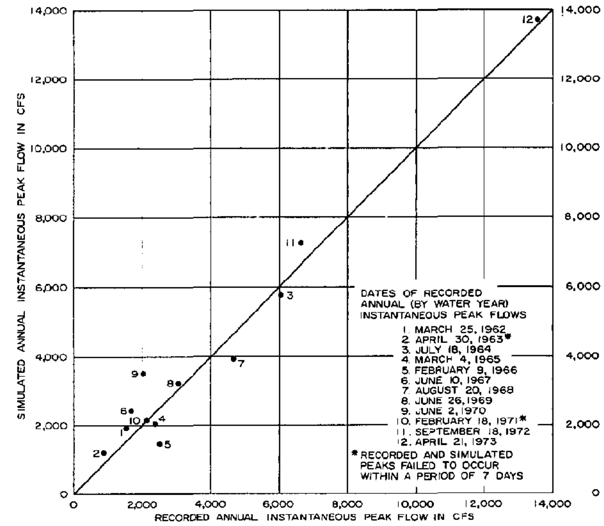
RECORDED AND SIMULATED DISCHARGE-FREQUENCY RELATIONSHIPS FOR THE MENOMONEE RIVER AT THE WAUWATOSA GAGE WATER YEARS 1962-1973



Source: SEWRPC.

Figure 81

RECORDED AND SIMULATED ANNUAL INSTANTANEOUS PEAK FLOWS FOR THE MENOMONEE RIVER AT THE WAUWATOSA GAGE WATER YEARS 1962-1973



Source: SEWRPC.

Honey Creek. Most flood stage data were for the April 1973 flood because this was the flood of record in most of the watershed and because the flood occurred during the preparation of the Menomonee River watershed plan and, therefore, the Commission staff was able to collect accurate high water data during and immediately after this flood event.

The calibration process consisted of comparing plotted 10-, 50-, and 100-, and 500-year flood stage profiles as obtained with Hydraulic Submodel 2 to historic high water marks. The relative position of the simulated and recorded flood stages was examined for consistency. For example, inasmuch as the April 1973 flood was determined to be approximately a 100-year recurrence interval event along the lower Menomonee River, a close correlation would be expected between existing land use-floodland development 100-year recurrence flood stage profiles obtained from Hydraulic Submodel 2 and actual high water marks obtained during or immediately after that event.

In those instances where an inconsistent relationship existed between simulated and historic flood stages, the problem was normally resolved by an adjustment in channel or floodplain Manning roughness coefficient. In some cases, improvements were made in the manner in which the channel-floodplain shape or bridge or culvert geometry was represented.

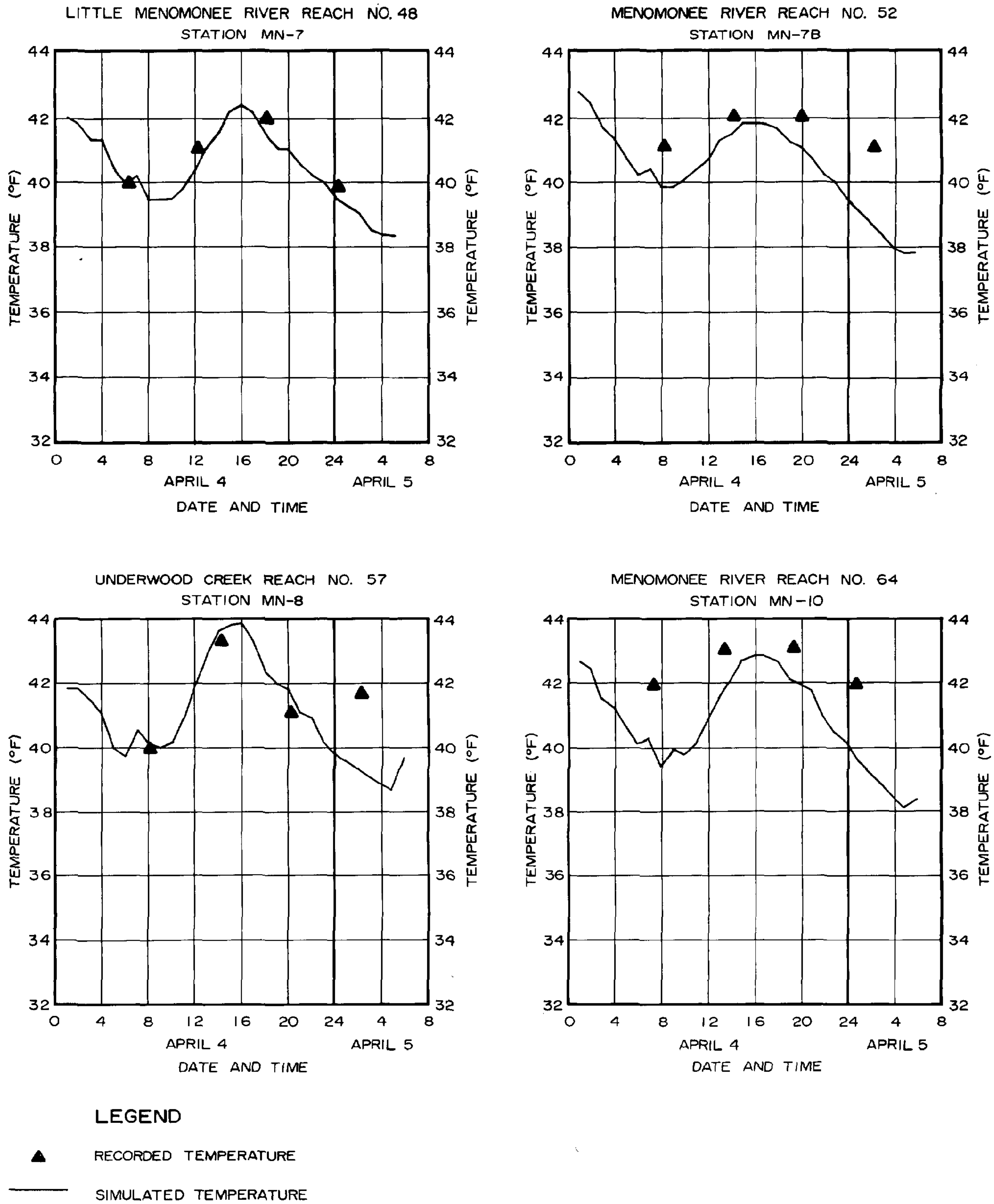
Water Quality Submodel: After completing calibration of the Hydrologic Submodel and Hydraulic Submodel 1, the water quality submodel calibration process was initiated. This sequential approach was used since successful water quality simulation is contingent upon effective hydrologic-hydraulic modeling inasmuch as runoff from the land surface and flow in the streams provide the transport mechanism for water quality constituents. Meteorologic, channel, diffuse source, and point source input data sets were prepared using the procedures described earlier in this chapter. With respect to calibration data, the Water Quality Submodel was calibrated using the results of three 24-hour watershedwide field surveys carried out, as described in Chapter VII of this volume, under the Menomonee River watershed planning program.

For each of the three synoptic surveys, the calibration process was initiated by concentrating on the most upstream stations in the watershed and achieving an acceptable correlation between the observed water quality at those locations and the results obtained with the Water Quality Submodel. After achieving a successful calibration with emphasis on six parameters—temperature, dissolved oxygen, phosphate-phosphorus, nitrogen forms, fecal coliform, and carbonaceous biochemical oxygen demand—the calibration effort then moved to the next downstream station. This process of calibration at successive stations down through the watershed was continued with some necessary iteration to upstream stations, until a watershedwide calibration was achieved with data from the first synoptic survey. The calibration procedure was initiated with the one spring event, after which summer survey data were used to complete the initial calibration of the Water Quality Submodel.

An example of the results obtained with the Water Quality Submodel calibration are presented in Figure 82 in the form of a graphical comparison of recorded and simulated water temperatures at four locations in the watershed during the April 4 and 5, 1973, synoptic survey. Simulated values are seen to approximate the recorded values for the survey and exhibit the expected diurnal fluctuation in surface water temperature. Table 79 compares average daily observed and simulated values of nine

Figure 82

RECORDED AND SIMULATED WATER TEMPERATURES AT FOUR LOCATIONS IN THE MENOMONEE RIVER WATERSHED: APRIL 4 AND 5, 1973



Source: SEWRPC.

Table 79

MEASURED AND SIMULATED MEAN DAILY CONSTITUENT CONCENTRATIONS FOR THE APRIL 4 AND 5, 1973, SYNOPTIC SURVEY

Sampling Station			Water Quality Constituents[a]								
Stream	Number	Reach	Temperature (°F)	Dissolved Oxygen	Fecal Coliform Bacteria[b]	Specific Conductance[c]	NH_3-N	NO_2-N	NO_3-N	PO_4-P	$CBOD_u$
Menomonee River	Mn-1	8	40.5	10.5	26	707	0.10	0.022	2.84	0.046	1.9
			40.1	9.9	20	713	0.13	0.024	2.71	0.11[d]	3.7
	Mn-2	18	40.8	10.8	30	734	0.21	0.070	2.72	0.481	2.6
			41.5	10.1	20	745	0.14	0.049	2.72	0.29[e]	--
	Mn-3	22	39.7	10.6	27	726	0.18	0.056	2.73	0.376	2.3
			41.0	10.4	28	773	0.15	0.042	2.39	0.34[d]	--
	Mn-4	28	40.1	11.4	140	796	0.50	0.065	2.23	0.546	3.7
			41.2	11.6	5,000	785	0.30	0.054	2.30	0.42[d]	--
	Mn-5	30	40.8	11.5	86	861	0.53	0.063	2.19	0.557	3.4
			41.7	11.0	73	877	0.59	0.060	2.18	0.44[e]	5.3
	Mn-6	31	39.9	11.8	94	868	0.52	0.061	2.23	0.545	3.2
			41.2	10.7	105	890	0.64	0.062	2.50	0.50[e]	--
	Mn-7a	50	40.5	11.8	85	887	0.43	0.050	2.21	0.397	3.1
			41.7	11.0	185	923	0.45	0.065	2.44	0.47[d]	--
	Mn-7b	52	40.3	12.0	198	937	0.42	0.051	2.13	0.401	3.0
			41.5	12.2	185	921	0.45	0.065	2.12	0.51[d]	--
	Mn-10	64	40.8	11.9	156	729	0.32	0.048	1.90	0.330	2.7
			42.4	11.1	1,210	932	0.36	0.066	1.63	0.32[e]	4.7
Little Menomonee River	Mn-7	48	40.3	15.8	114	896	0.17	0.029	2.29	0.112	3.0
			40.6	11.1	48	937	0.10	0.037	2.18	0.09[d]	--
	Mn-11	40	40.8	11.3	48	707	0.11	0.023	2.72	0.053	2.1
			40.6	10.8	58	806	0.18	0.026	3.41	0.08[d]	3.9
	Mn-17	46	41.4	11.7	201	1,041	0.16	0.042	1.99	0.144	2.3
			39.9	10.8	78	886	0.18	0.050	1.57	0.12[d]	3.3
Little Menomonee Creek	Mn-16	38	43.2	11.1	37	707	0.09	0.023	2.86	0.044	1.6
			40.1	11.9	395	873	0.36	0.042	3.01	0.14[d]	3.5
Underwood Creek	Mn-8	57	40.8	11.8	167	944	0.15	0.048	1.99	0.154	2.3
			40.5	12.0	500	1,153	0.24	0.064	1.57	0.16[d]	--
	Mn-12	55	39.4	11.7	95	909	0.15	0.041	2.18	0.127	3.1
			40.5	11.7	50	1,056	0.23	0.036	1.54	0.07[d]	--
Honey Creek	Mn-9	63	42.6	12.1	199	931	0.13	0.046	1.70	0.210	1.9
			44.8	11.0	465	952	0.24	0.066	1.30	0.27[d]	5.3
	Mn-13	61	43.9	11.8	188	900	0.11	0.052	1.88	0.233	1.9
			39.7	11.4	115	895	0.18	0.068	1.43	0.17[d]	--

NOTE: Top value is average of simulated values and bottom value is average of measured values.

[a] *Values are in mg/l except as indicated.*

[b] *Values are in MFFCC/100 ml.*

[c] *Values are in micro-mhos/cm at 77° F.*

[d] *Measured total phosphorus was used as an estimate of PO_4-P because reliable measured dissolved phosphorus values were not available.*

[e] *Measured dissolved phosphorus was used as an estimate of PO_4-P.*

Source: Wisconsin Department of Natural Resources, U. S. Geological Survey, and SEWRPC.

water quality parameters at each of seventeen instream stations for the April 4 and 5, 1973 synoptic survey. The table indicates that the model simulates temperature, dissolved oxygen, specific conductance, and all nitrogen forms well while yielding overall acceptable results with respect to fecal coliform counts, phosphate-phosphorus, and carbonaceous biochemical oxygen demand.

SUMMARY

A quantitative analysis of stream flow and water quality conditions under existing and possible alternative future conditions is a fundamental requirement of any comprehensive watershed planning effort. Discharge, stage, and water quality at any point and time within the stream system of a watershed are a function of three factors: meteorological conditions and events, the nature and use of the land, and the characteristics of the stream system.

The ideal way to investigate the behavior of the hydrologic-hydraulic-water quality system of a watershed would be to make direct measurements of the phenomena involved. Such a direct approach is not generally feasible because of the extremely high costs, the improbability of the occurrence of critical events, and the inability to evaluate the impacts of possible future land and stream conditions. Hydrologic-hydraulic-water quality-flood economics simulation, accomplished with a set of interrelated digital computer programs, is an effective way to conduct the quantitative analysis required for watershed planning. Such a water resource simulation model was developed for and used in the Menomonee River watershed planning program. The various submodels comprising the model were selected from existing computer programs or were developed by the Commission staff so that the composite model would meet the watershed study needs as stated in the form of nine criteria. The Water Resource Simulation Model developed for and used in the Menomonee River watershed planning program consists of the following five submodels: the Hydrologic Submodel, Hydraulic Submodel 1, Hydraulic Submodel 2, the Water Quality Submodel, and the Flood Economics Submodel.

The principal function of the Hydrologic Submodel is to determine the volume and temporal distribution of runoff from the land to the stream system. The basic physical unit on which this submodel operates is the hydrologic land segment which is defined as a land drainage unit exhibiting a unique combination of meteorological factors, land use-cover, and soils. The submodel, operating on a time interval of one hour or less, continuously and sequentially maintains a water balance within and between the various interrelated hydrological processes as they occur with respect to the land segment. Meteorological data and land data constitute the two principal types of input for operation of the Hydrologic Submodel. The key output from the submodel consists of a continuous series of runoff quantities for each hydrologic land segment in the watershed.

The function of Hydraulic Submodel 1 is to accept as input the runoff from the land surface as produced by the Hydrologic Submodel, to aggregate it, and to route it through the stream system, thereby producing a continuous series of discharge values at predetermined locations along the surface water system of the watershed. Application of this submodel requires that the stream system be divided into reaches and impoundment sites. Input for Hydraulic Submodel 1 consists of parameters describing the reaches and impoundment sites as well as the output from the Hydrologic Submodel.

Hydraulic Submodel 2 computes flood stages attendant to flood flows of specified recurrence intervals as produced by Hydraulic Submodel 1. Use of this submodel requires, in addition to the output of Hydraulic Submodel 1, a very detailed description of the watershed stream system including channel-floodplain cross-sections, Manning roughness coefficients, and complete physical descriptions of all hydraulically significant culverts, bridges, and dams. The principal output from Hydraulic Submodel 2 consists of flood stage profiles which are used to delineate flood hazard areas and to provide input to the Flood Economics Submodel.

The Flood Economics Submodel performs two principal functions: calculation of average annual flood damages to floodland structures and computation of the costs of alternative flood control and floodland management measures such as floodproofing and removal of structures, the construction of earthen dikes and concrete floodwalls, and major channelization works. In addition to flood stage and probability information obtained from Hydraulic Submodel 2, input to the Flood Economics Submodel includes basic cost data and parameters describing the physical aspects of riverine area structures, dikes and floodwalls, and channelized reaches. Output from the model consists of the monetary costs and benefits of each floodland management alternative that is formulated and tested.

The Water Quality Submodel simulates the time-varying concentration, or levels, of the following nine water quality indicators at selected points throughout the surface water system: temperature, dissolved oxygen, fecal coliform bacteria, phosphate-phosphorus, total dissolved solids, carbonaceous biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrogen, and nitrite-nitrogen. Operating on a reach-by-reach basis, the submodel continuously determines water quality as a function of reach inflow and outflow, dilution, and biochemical processes. Input to the Water Quality Submodel consists of output from the Hydrologic Submodel, channel data, meteorologic data, and diffuse and point source data. Output from the submodel consists of a continuous series of water quality levels at selected points on the watershed stream system.

The largest single work element in the preparation and application of the Water Resources Simulation Model consists of data base development. This includes the acquisition, verification, and coding of the data needed to operate, calibrate, test, and apply the model. The model data base for the watershed consists of a large, primarily computer-based file subdivided into six categories: meteorological data, land data, channel data, riverine area structure data, diffuse source data, and point source data. The meteorological data set is the largest because it contains 35 years of semimonthly, daily, or hourly information for seven types of meteorological data. The data base was assembled using data collected under other Commission planning programs, inventory data collected by the Commission and consultants under the Menomonee River watershed planning program, and data from other sources such as the National Climatic Center.

Many of the algorithms incorporated within the Water Resource Simulation Model are approximations of complex natural phenomena and, therefore, before the model could be used to simulate hypothetical watershed conditions, it was necessary to calibrate the model. Calibration consists of comparing simulation model results with factual historic data and, if a significant difference is found, making parameter adjustments to adapt the model to the effects of the natural and man-made features of the planning region and the watershed. The three types of validation data available for calibration of the Water Resources Simulation Model were streamflow data, flood stage data, and water quality data. The initial calibration of the hydrologic-hydraulic portions of the model were conducted on subwatersheds outside of but close to the Menomonee River watershed that were essentially spatially homogeneous with respect to soils, slope, and land use-cover and had combinations of these three key land characteristics that were similar to those found in land segments of the Menomonee River watershed. The underlying objective was to use the calibration process to determine land parameters for the homogeneous subwatersheds which could, in turn, be applied to the Menomonee River watershed—a heterogeneous basin containing many different soils, slope, and land use combinations.

Three test areas were selected for the initial calibration runs—the 24.8-square-mile rural and urban Oak Creek subwatershed in Milwaukee County, the 57.9-square-mile rural Root River Canal subwatershed in Racine County, and the 49.6-square-mile rural East Branch of the Milwaukee River subwatershed in Fond du Lac County. The iterative calibration process, which consisted essentially of model runs followed by parameter adjustments, was carried out for each of the three subwatersheds until close agreement was achieved between historic and simulated annual runoff volumes, runoff event hydrographs, and discharge-frequency relationships.

After completing calibration of the Hydrologic Submodel and Hydraulic Submodel 1 on the three test subwatersheds, the calibration process was applied to the Menomonee River watershed. The Hydrologic Submodel and Hydraulic Submodels 1 and 2 were successfully calibrated by comparing the simulated discharges to daily streamflows at the U. S. Geological Survey stream gaging station on the Menomonee River gage in Wauwatosa, and to peak discharges recorded at two partial record USGS gages and by comparing simulated stages to historic stages available at many locations around the watershed.

The Water Quality Submodel was calibrated to the surface water system of the Menomonee River watershed by means of data obtained from three 24-hour synoptic water quality surveys conducted under the watershed planning program. These synoptic water quality surveys conducted on April 4 and 5, 1973; July 18 and 19, 1973; and August 6 and 7, 1974, represented a range of meteorologic, hydrologic, and hydraulic conditions, and when data from them was used in conjunction with model input parameters reported in the literature, an acceptable calibration was achieved.

Chapter IX

NATURAL RESOURCE BASE, ENVIRONMENTAL QUALITY, AND RECREATION—RELATED ACTIVITIES

INTRODUCTION

The Menomonee River watershed contains only remnants of important natural resource elements such as streams, woodlands, wetlands, and wildlife habitat, and most of the elements that do remain are generally of lower quality. Nevertheless, such elements of the natural resource base are important not only to essential active and passive recreational pursuits but also to the maintenance of a healthy ecological balance within the watershed. Population growth and urbanization within the Region and the watershed are increasing the significance of these remaining elements, while at the same time impairing their quality and reducing their quantity.

This chapter has three purposes. The first is to describe the historic and existing conditions of those elements of the natural resource base that have direct impact on watershed environmental quality and on the provision of opportunities for recreational pursuits and activities. The second purpose is to clearly identify the problems associated with those elements of the natural resource base and their potential for maintaining or enhancing environmental quality and for accommodating additional recretional activities. The third purpose is to identify the gross recreational land needs within the Menomonee River watershed to the year 2000 and the relationship between those land needs and both existing and potential outdoor recreational lands.

Data and other information about the natural resource base and existing and potential outdoor recreation and related open space sites as set forth in this chapter are based upon or are an extension of the summary description presented in Chapter III of this volume.

STREAMS

Streams are complex ecological systems with particular importance for outdoor recreational activities since many of those activities either require the presence of water or are enhanced by its proximity. Fishing, swimming, and boating are examples of the former whereas picnicking, hiking, and pleasure driving are examples of the latter. The recreational importance of the Menomonee River watershed stream system is heightened by the fact that there are no major lakes—50 acres or more in size—located within the watershed and, therefore, water-oriented recreational activity in the watershed is limited exclusively to the stream system.

Fishery

Historic Findings: During the first half of the nineteenth century, the estuarine area in the vicinity of the confluence of the Menomonee, Milwaukee, and Kinnickinnic Rivers was a wetland normally covered by about two feet of water and containing an abundance of fish.[1] In 1844 a bridge was constructed across the Milwaukee River at Walker's Point, downstream of the Menomone River confluence, and that structure soon became a popular fishing spot. Pickerel, suckers, and lake sturgeon were regularly observed running upstream in the spring.[2]

Based on interviews conducted during preparation of the Menomonee River Watershed Planning Program Prospectus, watershed residents indicated that within their "living memories" recreational fishing was enjoyed in the Menomonee River and some of its tributaries. Bluegill, other sunfish, perch, and bullheads were taken from various locations along the lower third of the Menomonee River up to about 1940.

A 300-foot-long reach of the Menomonee River immediately downstream of W. Burleigh Street (River Mile 9.73) was subjected to electrical shocking by the Wisconsin Conservation Department (now a part of the Wisconsin Department of Natural Resources) on July 10, 1952, in order to determine the number and type of fish present in the streams.[3] The channel was about 30 feet wide through the surveyed reach and the river flowed at a depth of about one foot. A water temperature of 70°F was recorded and the water was described as being very turbid at the time of the shocking operation. Of the total of 277 fish taken, about 10 percent represented species very tolerant to pollution, about 40 percent were tolerant species, and the remaining 50 percent intolerant species. Although the July 1952 data at the W. Burleigh Street crossing of the Menomonee River indicated the existence of fairly diverse fish population, there were very few or no representatives of the more popular species of sport fish such as bluegill, sunfish, and perch.

A fish kill occurred on the Menomonee River in what is now the Village of Menomonee Falls on June 19, 1953.[4] A June 20, 1953, field investigation by the Wisconsin Conservation Department concluded, on the basis of

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[1] *James S. Buck, Pioneer History of Milwaukee, Milwaukee News Company, 1876, 292 pp.*

[2] *John G. Gregory, History of Milwaukee, Volumes I and II, Clarke Publishing Company, 1931.*

[3] *Wisconsin Conservation Department, Intraoffice Memorandum to C. W. Threinen from J. Klingbiel, October 1, 1952.*

[4] *Wisconsin Conservation Department, Intraoffice Memorandum to C. W. Threinen from D. Mraz, June 20, 1953.*

a large number of dead bullheads still present in the area, that the fish kill was very extensive. The investigation also revealed the occurrence of an even more extensive fish kill in the same area about three weeks earlier. The investigation concluded that a probable factor contributing to the fish kill was discharge of washwater from a milk condensery in Germantown.

In June of 1969, fuel oil leaking from an interregional pipeline crossing the Menomonee River in Germantown caused a large fish kill. Large numbers of small largemouth bass (see Figure 83), a popular game fish, were included in the fish kill along with other fish and aquatic life. Although they were small, the presence of large numbers of largemouth bass suggests that portions of the stream system may have the potential to support recreational fishing.

Figure 83

FISH KILL ON THE MENOMONEE RIVER IN THE VILLAGE OF GERMANTOWN: JUNE 1969

In June 1969 fuel oil leaking from an interregional pipeline crossing the Menomonee River in the Village of Germantown caused a large fish kill. Large numbers of small largemouth bass, a popular game fish, were included in the kill, suggesting that portions of the stream system have the potential to support recreational fishing.

Source: The Milwaukee Journal Company.

The above brief account of historic events related to the watershed fishery suggests that the condition of the stream fishery, and therefore the enjoyment derived from it by watershed residents, has declined significantly over the recent past. Furthermore, this brief historic account indicates that a stream fishery in a small watershed is sensitive to the varied activities and conditions associated with increasing population levels and urban development such as discharges from commercial and industrial concerns, oil spills, sewage treatment plant discharges, and runoff of pesticides, herbicides, and fertilizers from both agricultural and urban lands.

Existing Conditions: The fish population of the Menomonee River watershed stream system was inventoried in late summer 1973 by the Wisconsin Department of Natural Resources, Bureau of Research. These field studies were conducted to determine the current status of the watershed stream fishery with respect to the number of fish present and the species represented and, equally important, to determine the potential for further fishery development so as to satisfy some of the water-oriented recreational needs of the watershed residents.

Inventory Procedure: A fish shocking technique was utilized in the fishery inventory at each of 28 stations established on the surface water system. Of the total of 28 stations, 24 were located directly on the stream system and four were located on ponds hydraulically connected to the stream system. Stream shocking stations were selected to be representative of the major streams in the watershed and to encompass the full spectrum of natural to channelized conditions. The locations of the 28 shocking stations are shown on Map 23. Information about the stations such as channel width, flow depth, and water conditions are provided in Table 80.

Depending on the width and depth of the stream reach at the sampling site, shocking was accomplished with one of two units. A small 220-volt direct current backpack shocker was used in narrow, shallow reaches and a larger 250-volt direct current shocker carried in a small boat was used in wider and deeper streams. The shocking process proceeded in an upstream direction, and the fish were netted after floating to the surface as a result of being temporarily stunned by the electrical charge. The captured fish were identified by species and counted. The length of game fish, panfish, and larger nongame fish was determined, and scale samples were taken in order to determine the age of the captured fish. Essentially all fish stunned in the stream were netted and enumerated with the exceptions of some minnows at stations Mn 1 and Mn 3. Most of the netted fish were released after examination. The exceptions were some fish that could not be readily identified in the field and they were taken to a laboratory for further investigation. The shocking procedure used in the four ponds differed from the stream procedure in utilizing a sampling procedure that consisted of shocking about 300 feet of shoreline in one to three feet of water.

Table 80

FISH SHOCKING STATIONS IN THE MENOMONEE RIVER WATERSHED

Watercourse	Civil Division	Station Number[a]	Station Type: Instream	Station Type: Pond	Ecologic Unit	Stream Crossings at or Near Station: Name	Stream Crossings at or Near Station: River Mile	Vegetal Condition: On Banks	Vegetal Condition: Instream	Channel Width (feet)	Flow Depth (feet)	Channel Bottom Conditions	Observed Water Quality	Comments
Menomonee River main stem	Village of Germantown	1	X		I	Freistadt Road and STH 145	27.23	Grasses and trees along both banks	N/A[b]	15-20	2-5	Large deposits of silt over gravel	Turbid	--
Menomonee River main stem	Village of Germantown	2	X		I	Mequon Road (STH 167)	25.93	Reed-canary grasses at downstream end	N/A	20-25	1-3	Deep silt over gravel and rocks	Turbid	Turbidity caused by upstream development. Upstream banks are bare
Menomonee River main stem	Village of Germantown	3	X		I	CTH Q between STH 175 and USH 41-45	23.47	Reed-canary grass on both banks	N/A	15-20	1-4	Mud and gravel	Turbid	--
Menomonee River main stem	Village of Menomonee Falls	4	X		II	Arthur Road	21.48	Grasses, brushes, and trees	N/A	5-10	1	Gravel and rock	Clear	--
Menomonee River main stem	Village of Menomonee Falls	5	X		II	Lilly Road between STH 175 and USH 41-45	19.74	Trees and reed-canary grass	N/A	10-20	1-2	Silt over gravel and rock	Turbid	--
Menomonee River main stem	City of Milwaukee	6	X		II	Good Hope Road	17.34	Reed-canary grass and brush	Aquatic vegetation abundant	30-35	1	Gravel and rock with some silt	Clear	--
Menomonee River main stem	Village of Menomonee Falls	7	X		II	Silver Spring Road	14.73	Grasses, brush, and trees	N/A	20-30	1/2-2	Gravel and rock	Clear	--
Menomonee River main stem	City of Wauwatosa	8	X		III	Capitol Drive	11.2	Grasses and trees	Arrow Root	20-50	1-4	Gravel and rock with some mud	Turbid	--
Menomonee River main stem	City of Wauwatosa	9	X		III	North Avenue	8.5	Trees and shrubs	N/A	30-40	1-4	Gravel and rock with some mud	Clear	--
Menomonee River main stem	City of Wauwatosa	10	X		III	N. 70th Street	6.10	Trees and shrubs	N/A	20-40	1-5	Gravel and rock	Fairly clear	--
Menomonee River main stem	City of Wauwatosa	11	X		III	Hawley Road	5.15	Wooded	N/A	20-40	1-3	Gravel and rock	Clear (gasoline floating on water)	Steep banks and water smells foul
West Branch of the Menomonee River	Village of Germantown	12	X		I	Maple Drive north of Freistadt Road	1.16	Grasses, brushes, and trees	N/A	3- 4	1/2-1	Gravel and rock	Clear	--
Willow Creek	Village of Germantown	13	X		I	STH 175 and CTH "Y"	1.15	Grasses	N/A	3- 6	1/2-2	Gravel and rock	Clear	--
Little Menomonee River	City of Mequon	14	X		V	Mequon Road (STH 167)	9.12	N/A	N/A	1- 3	1/2	Mud	Clear	--
Little Menomonee River	City of Mequon	15	X		V	County Line Road (CTH Q)	6.91	Reed-canary grasses	Dense aquatic vegetation	10-15	1- 3	Silt over gravel	Turbid	--
Little Menomonee River	City of Milwaukee	16	X		VI	STH 100 north of W. Hampton Avenue	0.09	Grasses, brush, and trees	Arrow Root	10-40	1/2-3	Mud and clay	Turbid	--
Little Menomonee Creek	City of Mequon	17	X		V	Freistadt Road (CTH F)	2.25	Grasses	N/A	1- 3	1/2-1	Silt over gravel	Clear	--
Little Menomonee Creek	City of Mequon	18	X		V	Mequon Road (STH 167)	1.03	N/A	N/A	3- 5	1/2-2	Silt over gravel	Clear	--
Noyes Creek	City of Milwaukee	19	X		VI	N. 91st Street and Denver Avenue	0.21	Cut grass	N/A	3	1/2	Rock and mud	N/A	Channel lined with concrete
Underwood Creek	City of Wauwatosa	20	X		VII	End of N. 106th Street	1.66	Cut grass	N/A	10	1-3	Concrete	Clear	Channel lined with concrete
South Branch of the Underwood Creek	City of West Allis	21	X		VII	End of 120th Street	1.75	Cut grass	Dense rooted aquatics	15-25	1-3	Silt (2 feet-3 feet deep) on concrete	Fairly clear	Channel lined with concrete
Honey Creek	City of West Allis	22	X		VIII	W. Arthur Avenue	4.32	Cut grass	N/A	1- 3	1/2	Concrete	Clear	Channel lined with concrete
Honey Creek	City of Wauwatosa	23	X		VIII	100 yards upstream of confluence with Menomonee River	.005	Shrubs and trees	N/A	5-20	1/2-2	Gravel and rock	N/A	Flowing through
Woods Creek	City of Milwaukee	24	X		IV	Veterans Administration Center	0.72	Cut grass	N/A	3- 5	1/2	Concrete	Clear	Channel lined with concrete
Menomonee Park Pond	City of Milwaukee	25		X	III	Between W. Burleigh Street and W. Sunset west of W. Menomonee River Parkway Drive	9.88	N/A	Dense aquatic vegetation	N/A	N/A	N/A	Turbid	Cans and bottles in pond. Direct inflow and outflow from the Menomonee River
Jacobus County Park Pond	City of Wauwatosa	26		X	III	South of Honey Creek Parkway Drive in Jacobus County Park	6.3	Turbid	Numerous rooted aquatics	N/A	N/A	Mud and clay	Turbid	Overflow outlet into the Menomonee River
McCarty County Park Pond	City of West Allis	27		X	VIII	South of W. Arthur Avenue in McCarty County Park	4.32	N/A	Few rooted aquatics	N/A	N/A	Mud and clay	Turbid	Overflow outlet into Honey Creek
Woods Pond	City of Milwaukee	28		X	IV	Veterans Administration Center	0.72	N/A	Blue-green algal and few rooted aquatics	N/A	N/A	Mud and clay	Turbid	Overflow outlet to the Woods Creek. Turbidity due to blue-green algal

[a] *A fish shocking station consists of a reach approximately 300 feet in length.*

[b] *Not applicable.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Inventory Findings: As indicated in Table 81, and Appendix F, a total of 4,701 fish representing 24 species were taken at the 28 stations during the shocking program which was carried out on August 6 through 8 and on September 10, 1973. The five most common species in order of decreasing abundance were the central mudminnow, green sunfish, black bullhead, goldfish, and brook stickleback. Figure 84 indicates in summary form for the 24 stream shocking stations the species that were captured, the number of fish of each species, and the approximate position of each species on a pollution tolerance scale.

The ranking of fish species on a pollution-tolerant scale is not meant to be a precise species-by-species statement of pollution tolerance but is instead intended to generally group species according to their pollution tolerance. Very tolerant fish can withstand large variances in water quality conditions, and are, therefore, found in both good-quality and polluted waters. Fish classified as tolerant typically exist in surface waters exhibiting less water quality variation than the very tolerant fish. Clean water or intolerant fish are, relative to the other two categories, very limited in the range of water quality conditions that they can exist in and therefore usually inhabit those reaches exhibiting minimal environmental stress. Inasmuch as a stream is a dynamic system and fish are mobile animals, less tolerant fish occasionally may find and temporarily reside in localized niches that are of a higher quality than the overall quality of the stream.

A total of 3,899 fish representing 23 species were captured in the fish shocking surveys at the 24 instream stations. Of this total, 2,421 fish, or 62.1 percent, were classified as being very tolerant to organic pollution; 1,038, or 26.6 percent, were classified as being somewhat pollution-tolerant, and the remaining 440, or 11.3 percent, were considered pollution-intolerant. There were almost eight times as many pollution-tolerant fish taken in the survey as there were pollution-intolerant fish.

A desirable fish population is one that contains a diversity of species distributed among the various tolerance levels with the pollution-intolerant fish being dominant. This desirable condition is the converse of that existing in the Menomonee River watershed. Inasmuch as the fish population serves as an index of stream water quality, the dominance of very tolerant and tolerant fish in the watershed stream system is another manifestation of the poor water quality conditions that generally exist in the watershed as documented in Chapter VII of this volume.

Of the 23 species of fish captured at the 24 instream stations, only the following five species are considered to be of sport fishing value: black bullhead, green sunfish, pumpkinseed, bluegill, and largemouth bass.[5] Considering the watershed as a whole, fish of these five species amounted to only 17 percent of the total number of fish that were captured during the instream fish shocking survey. This clearly indicates that the Menomonee River watershed presently supports only a minimal recreational fishery.

Although fish sampling stations were rather uniformly distributed over the watershed, the number of fish captured at those stations was not uniformly distributed. For example, of the 3,899 fish taken at the 24 instream stations, 2,351—or 60 percent—were taken at just three stations, Stations 1, 2, and 3 on the Upper Menomonee River in the Village of Germantown. The relatively large number of fish captured at these three stations does not, however, mean that a desirable fishery exists in that portion of the watershed since about 81 percent of the fish taken at those stations were categorized as being very tolerant to pollution.

A stream-by-stream comparison of the number and type of fish captured during the fish shocking survey indicates a striking spatial variation in fishery characteristics. The

[5] *Scientific names of fish species are given in Appendix G.*

Table 81

RESULTS OF FISH SHOCKING SURVEY IN THE MENOMONEE RIVER WATERSHED BY STREAM: AUGUST AND SEPTEMBER 1973

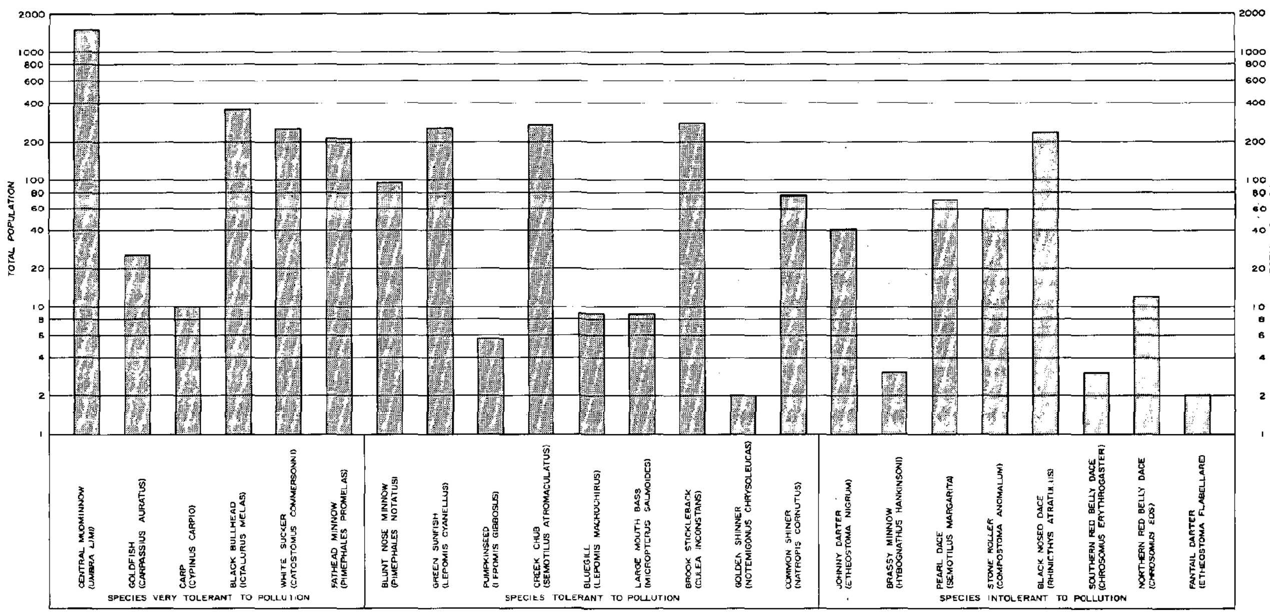
Stream	Number of Stations	Population and Number of Species According to Relative Tolerance to Organic Pollution												Totals								Ratios of Very Tolerant, Tolerant, and Intolerant Populations
		Very Tolerant				Tolerant				Intolerant				All Fish				Sport Fish[a]				
		All Fish		Sport Fish[a]		All Fish		Sport Fish[a]		All Fish		Sport Fish[a]										
		Species	Population	Species	Population	Species	Population	Species	Population	Species	Population	Species	Population	Species	Species per Station	Population	Population per Station	Species	Species per Station	Population	Population per Station	
Upper Menomonee River	7	6	2,251	1	356	8	584	3	183	5	180	0	0	19	3	3,015	431	4	4	539	77	12.51/3.24/1.0
Lower Menomonee River	4	4	22	0	0	3	30	1	7	1	8	0	0	8	2	60	15	1	4	7	2	2.75/3.75/1.00
West Branch of the Menomonee River	1	3	72	0	0	3	60	1	22	4	58	0	0	10	10	190	190	1	1	22	22	1.24/1.03/1.00
Willow Creek	1	3	24	0	0	4	64	1	6	5	163	0	0	12	12	251	251	1	1	6	6	0.15/0.39/1.00
Little Menomonee River	3	4	21	1	3	4	114	1	2	1	5	0	0	9	3	140	47	2	4	5	2	4.20/22.80/1.00
Little Menomonee Creek	2	3	4	0	0	3	17	1	8	1	2	0	0	7	4	23	12	1	4	8	4	2.00/8.50/1.00
Noyes Creek	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	--
Underwood Creek	1	0	0	0	0	2	107	0	0	2	24	0	0	4	4	131	131	0	0	0	0	0.00/4.46/1.00
South Branch of Underwood Creek	1	3	24	0	0	5	55	4	53	0	0	0	0	8	8	79	79	4	4	53	53	--
Honey Creek	2	1	3	0	0	1	7	1	7	0	0	0	0	2	1	10	5	1	4	7	4	--
Woods Creek	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	--
Totals	24	6	2,421	1	359	9	1,038	4	288	8	440	0	0	23	--	3,899	--	5	--	647	--	5.50/2.36/1.00

[a] *Sport fish are defined as the following species: black bullhead (Ictalurus melas), green sunfish (Lepomis cyanellus), pumpkinseed (Lepomis gibbosus), bluegill (Lepomis macrochirus), and largemouth bass (Micropterus salmoides). The yellow perch (Perca flavescens) has been omitted from this list as it was collected only at the pond stations.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 84

RESULTS OF FISH SHOCKING SURVEY CONDUCTED IN THE MENOMONEE RIVER WATERSHED ON AUGUST 6-8 AND SEPTEMBER 10, 1973



Source: Wisconsin Department of Natural Resources and SEWRPC.

Upper Menomonee River, which is defined as that portion of the main stem of the Menomonee River above its confluence with the Little Menomonee River, yielded 431 fish per station. The Lower Menomonee River, which encompasses all of the main stem of the Menomonee River downstream of the Little Menomonee River, yielded only 15 fish per station. This indicates that the Lower Menomonee River maintains a significantly reduced and dispersed fish population compared to the Upper Menomonee River.

The single shocking station on Willow Creek, a headwater tributary of the Menomonee River, yielded about 250 fish. The most dominant fish were those in the pollution-intolerant category which is indicative of good water quality. Almost 190 fish were captured at the single station on the West Branch of the Menomonee River, another headwater tributary. This relatively high number and the approximately uniform distribution of fish between very tolerant, tolerant, and intolerant species also generally indicate good water quality.

The single Underwood Creek shocking station yielded about 130 fish in the tolerant and intolerant categories. The ratio of tolerant to intolerant fish, however, was about 4.5 indicating unsatisfactory water quality conditions. Fish shocking stations on the Little Menomonee River, Little Menomonee Creek, South Branch of Underwood Creek, and Honey Creek yielded from about 5 to 80 fish per station. In all cases, fish in the very tolerant and tolerant categories were dominant compared to the intolerant categories, clearly indicating the low level of water quality in these streams. No fish were taken at the single stations on Noyes Creek, a tributary to the Little Menomonee River, or on Woods Creek, a tributary to the Menomonee River.

Only eight fish species were identified in the four ponds that were sampled, and all of these species were categorized as being either very tolerant or tolerant to pollution. Fish found in the ponds, listed in order of decreasing abundance, are green sunfish, goldfish, pumpkinseed, bluegills, yellow perch, black bullheads, carp, and the largemouth bass. Of the four ponds sampled, the Jacobus Park Pond exhibited the greatest diversity; a total of 325 fish were collected and identified from seven different species. Some of these ponds have been stocked for both aesthetic and recreational fishing purposes and, therefore, the existing fish population does not necessarily reflect a natural fish community.

In summary, the fishery survey data indicate that the Menomonee River watershed currently supports a limited fishery characterized by a dominance of fish that are generally tolerant to poor water quality. Portions of the watershed stream system, most notably the Lower Menomonee River, maintain significantly reduced and dispersed fish populations and are in some cases virtually devoid of fish life.

Potential Development: The existing fishery in the southern portions of the Menomonee River watershed stream system is presently of little value. If water quality conditions were improved, however, so as to be consistent with the water quality standards set forth in Chapter II of Volume 2 of this report, and if this could be accomplished without substantially reducing stream flow, a sport fishery with high recreational value probably could be developed. The potential fish population could include several species of darters, a diverse minnow population, northern pike, and some largemouth, smallmouth, and rock bass.

Development of a sport fishery in the lower portions of the watershed also could include introduction of larger anadromous fish, that is, those species that instinctively migrate from Lake Michigan up tributary streams for the purpose of spawning. The following six species of anadromous fish with sport fishing potential are known to exist in Lake Michigan and could instinctively use the Menomonee River for spawning runs: coho salmon, chinook salmon, Atlantic salmon, brook trout, brown trout, and rainbow trout.[6] Spawning runs occur in spring and fall when temperature and dissolved oxygen conditions would be satisfactory because of the higher runoff and streamflow that normally occur at these two times of the year. Although natural reproduction is very unlikely, it is probable that runs of anadromous fish could be established and sustained through a fish stocking program so as to provide a popular recreational activity. Similar fisheries have already been established on other southeastern Wisconsin streams tributary to Lake Michigan such as Sauk Creek in Ozaukee County, Oak Creek in Milwaukee County, the Root River in Racine County, and the Pike River in Kenosha County.

The potential recreational benefits of sport fishery based on spring and fall runs of anadromous fish would have to be weighed against the attendant problems. Law enforcement and control problems could occur as a result of large numbers of fisherman gathering at crowded public access points along the stream system during brief periods of the year. Likewise, pesticides, heavy metals, and other contaminants such as PCB's—polychlorinated biphenyls, a compound commonly used as a heat transfer fluid, a plasticizer, and an extender for pesticides, which are present in the Menomonee River and the Lake Michigan estuary—could accumulate in fish flesh in amounts sufficient to present a health hazard even though the fish would be in the Menomonee River and the estuary for only a relatively short period of their total life span. For example, mussels placed in the Menomonee and Milwaukee Rivers in 1969 accumulated high levels of the insecticides DDT (dichloro-diphenyl-trichloro-ethane) and Dieldrin, and fish samples collected from the lower Milwaukee River in 1966 and 1967 exhibied high Dieldrin levels.[7]

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[6] *W. Downs (Editor), Fish of Lake Michigan, University of Wisconsin Sea Grant College Program, 1974, 32 pp.*

[7] *U. S. Environmental Protection Agency, "An Evaluation of DDT and Dieldrin in Lake Michigan," EPA Series R3-72-003, 1972.*

Swimming

Historic and Existing Conditions: Interviews conducted during preparation of the Menomonee River Watershed Planning Prospectus indicated that the Menomonee River and some of its tributaries were used for wading and swimming up to about 1940. Wading and swimming sites along the Menomonee River included deeper water at locations such as the vicinity of the W. Burleigh Street crossing, near Hoyt Park, and as far downstream as Jacobus Park.

There is no evidence of wading and swimming activity in the watershed in recent years, particularly in the urban areas. This may be attributable to the general public perception of the polluted nature of the Menomonee River stream system. In addition, most of the 6.9-mile-long segment of the Little Menomonee River within Milwaukee County has been posted by the Milwaukee County Park Commission as a health hazard because of the presence of creosote in the bottom sediments. Water quality data presented in Chapter VII of this volume clearly indicate that most of the stream system is not presently suited for full body-contact recreation because of the potential for contacting pathogenic bacteria, because of the presence of creosote and other toxic materials, and because of such aesthetic factors as high turbidity, excessive growths of algae and other aquatic plants, and the presence of odor.

As discussed in Chapter V of this report, a large part of the watershed stream system has been modified for flood control or agricultural drainage purposes. For example, of the 72 miles of stream system in the watershed selected for development of detailed flood hazard data, about 48 miles, or 67 percent, are known to have undergone some type of manmade channel modification. This includes 15.8 miles of major channelization consisting of continuous and extensive deepening, widening, and straightening and extensive application of concrete or masonry to the channel bottom and side walls. Major channelization is concentrated in the older, urban areas of the watershed, most of it located within Milwaukee County on Underwood Creek, Honey Creek, and the Menomonee River. It is significant to note, however, that major channelization projects have not generally been carried out along most of the riverine areas lying within the Milwaukee County Park System. Therefore, the stream system in these areas remains relatively undisturbed in comparison to the adjacent urban complex. Major channelization, particularly the extensive use of concrete and the removal of natural vegetation, has an aesthetic impact that detracts from the potential use of a river reach for wading or swimming purposes. Furthermore, the algal and fungal growths typically found on the concrete inverts of such channels are extremely slippery and may constitute a safety hazard.

Another factor mitigating against the use of the watershed stream system for swimming is the generally shallow depths that exist during summer low-flow periods. These conditions exist even in the lower portions of the watershed where the Menomonee River passes through extensive public parklands. The maximum depth of flow in these areas during summer low-flow periods generally is less than three feet. Therefore, from a strictly physical perspective, there is not sufficient depth of flow during the summer period to provide adult recreational swimming. The depths would be adequate for wading and some swimming by children.

A final factor that may presently restrict wading and swimming in the watershed stream system is insufficient public access in the form of public parklands contiguous to the rivers and streams. Very little public parkland exists along the major streams in Ozaukee, Washington, and Waukesha Counties. A significant exception to the scarcity of public access to the stream system is Milwaukee County. For example, public lands lie along that 10.3-mile segment of the Menomonee River in Milwaukee County upstream of the Hawley Road crossing—a reach that has not been channelized—thus providing public access to about two-thirds of that section of the Menomonee River within the county. Public lands lie along 6.2 miles, or 90 percent of the length, of Little Menomonee River in the county, another essentially natural riverine area.

Potential Development: As described above, the Menomonee River watershed stream system cannot now support safe and enjoyable wading and swimming activities for the following four reasons: potentially dangerous water quality conditions, extensive channelization, insufficient flow depths, and inadequate public access. Assuming that the water use objectives and supporting standards are met by pollution abatement measures encompassed in the Menomonee River watershed plan, water quality conditions would be adequate for wading and swimming throughout all of the watershed stream system with the exception of the Menomonee River downstream of the Hawley Road crossing (River Mile 5.15); that portion of Underwood Creek downstream of Juneau Boulevard (River Mile 3.67); all of the South Branch of Underwood Creek; and all of Honey Creek. At the time that the watershed development objectives were formulated, recreational water use objectives—which include wading and swimming—were not assigned to the above four reaches because the extensive channel modifications in those riverine areas in combination with the close proximity of intensively developed industrial and commercial areas would detract considerably from the enjoyment of any water-oriented recreational activity even if the water quality met the supporting standards.

While water quality would be adequate for wading and swimming throughout most of the watershed stream system—with the exception of the four above named reaches—the recreational experience probably would be limited primarily to children because of the shallow depths likely to persist during the summer season. Because of the flow depth limitation, there is essentially no potential for developing adult swimming areas in the watershed stream system. Channelization would not detract significantly from the wading and swimming experience of children, either aesthetically or from a safety perspective, because most of the major channel modifications are contained within the four reaches excluded from the recreation objectives and it is assumed that these reaches would be posted as off-limits to wading and swimming.

The final hindrance to active wading and swimming activity for children in the watershed is lack of public lands along the major streams, particularly in the Ozaukee and Washington County portions of the watershed. This obstacle could be removed by public acquisition of selected riverine lands for park and related recreation uses, including the development of controlled wading and swimming areas.

In summary, then, the Menomonee River watershed stream system has the potential to support limited wading and swimming activities for children. For safety reasons, wading and swimming sites for children should be provided at riverine parks in conjunction with facilities for other recreational activities.

Boating

Historic and Existing Conditions: Historic information collected during preparation of the Menomonee River Watershed Planning Prospectus indicated that some limited boating activities were enjoyed on the watershed streams during periods of high water. This use has continued in recent times in that children have been observed riding rafts and other objects on the Menomonee River. The Menomonee River also receives occasional use by canoeists during low flow periods.

The absence of active and significant boating activity in the Menomonee River watershed may be attributable to three of the four factors that mitigate against wading and swimming; namely, inadequate water quality, extensive channelization, and shallow depths. Limited public ownership of riverine lands in the Ozaukee and Washington County portions of the watershed is not considered a problem for boaters since they are not likely to successfully use canoes or rafts in those headwater areas because of shallow flow depths. Furthermore, access to the streams in these areas can always be accomplished from public street and highway rights-of-way.

Substandard water quality interferes with the full enjoyment of boating because of both an aesthetically objectionable appearance of the water and shoreline and the fear of contacting disease or otherwise being harmed by contact with water containing pathogens, toxic materials, or other potentially harmful or dirty substances. Extensive channelization detracts from boating because of its negativetive aesthetic effect. Shallow depths limit the user to light, flat-bottomed crafts such as canoes and rubber rafts having minimum draft requirements and also restrict the user to certain locations within the stream system and to particular times of the year.

Potential Development: Boating in the Menomonee River watershed is, as discussed above, currently limited by water quality problems, extensive channelization, and shallow depths. If the recommended water use objectives are met by implementation of the Menomonee River watershed plan, stream water quality conditions would be safe for boating throughout all of the watershed stream system with the exception of the Menomonee River downstream of Hawley Road (River Mile 5.15), that portion of Underwood Creek downstream of Juneau Boulevard (River Mile 3.67), all of the South Branch of Underwood Creek, and all of Honey Creek.

Although the water quality conditions would be adequate for boating throughout the watershed stream system—with the exception of the four above named reaches—enjoyment of the recreational experience would be severely limited by shallow depths. Even canoeing and the use of rubber rafts would be restricted, both with respect to time and place within the basin depending on the channel configuration and on flow conditions. Channelization would not materially detract from the limited boating experiences that might be enjoyed in the watershed since most of the major channel modifications are contained within the four reaches excluded from recreation objectives. These reaches would presumably be posted as off-limits to recreational boating. In summary, then, the watershed stream system has the potential to support only minor boating activity limited exclusively to light, shallow draft boats such as canoes, skiffs, and rubber rafts.

Other Recreational Uses

While fishing, swimming, and boating require the presence of water, other outdoor recreational activities such as picnicking, hiking, cross-country skiing, and pleasure driving are enhanced by the proximity of water. The system of linear parkways and parkway drives developed within Milwaukee County along the stream system exemplifies the effective use of surface water resources to enhance both active and passive recreational activities. Although on a much smaller scale, a similar parkway exists in the Village of Menomonee Falls. Considerable potential remains in the Ozaukee, Washington, and Waukesha County portions of the watershed to acquire and develop sites that provide opportunities for public enjoyment of active and passive recreational activities in and near riverine areas.

WOODLANDS AND WETLANDS

The natural vegetation of a watershed at any given time is determined by, or results from, a variety of factors including climate, topography, pests, disease, occurrence of fire, soil characteristics, proximity of bedrock, drainage features, and, of course, the activities of man. Due to the temporal and spatial variability of these influencing factors and the sensitivity of vegetation to most of them, the vegetation of the watershed is a changing mosaic of different types.

The terrestrial vegetation of the watershed occupies sites which may be subdivided into two broad classifications: wetland and woodland. Wetlands are defined as those lands at least 10 acres in area which are wholly or partially covered with hydrophytes[8] and wet and spongy organic soils and which are generally covered with shallow standing water, intermittently inundated, or have a high water table. Woodlands are defined as lands at least 10 acres in area which are covered by a dense, concentrated stand of trees and associated undergrowth.

The location, extent, type, and quality of wetland and woodland areas in the Menomonee River watershed are key determinants of the environmental quality of the watershed; therefore, considerable effort was devoted under the watershed planning program to the inventory and analysis of the remaining woodland and wetland resources of the watershed. Such areas contribute to the beauty and visual diversity of the environment and potentially function as visual and acoustic shields or barriers. Woodland-wetland areas also serve important ecological functions since typically they are, on a unit basis, the biologically most productive areas of the watershed, providing continual wildlife range and sanctuary for native biota and helping to maintain surface water quality by acting as sediment and nutrient traps. Certain woodland and wetland areas can be excellent outdoor laboratories for educational and research activities. Finally, some woodland-wetland areas can support or complement certain outdoor recreation activities.

Historic Conditions

Prior to settlement of the watershed by Europeans, the upland areas of the watershed were covered by a predominantly medium wet or mesic forest composed of a variety of deciduous hardwoods, such as maple, beech, basswood, ironwood, red oak, and slippery elm. Tamarack, black ash, or shrubs dominated the wetter areas such as old glacial lake beds and other poorly drained low areas while silver maple and American elm grew in seasonally flooded sites along the major water courses. Depending on the periodic susceptibility to fire and water table levels, certain wetlands may have been open marshes dominated by combinations of cattails, grasses, sedges, and forbs. Additional information about the historic vegetation, based on U. S. Public Land Survey Records, is presented in Chapter III of this volume.

The extensive hardwood forests that once covered the entire Menomonee River watershed have now been reduced to only scattered remnants of woodlands and wetlands. A variety of factors, most of them directly related to the activities of man, has brought about this dramatic change in vegetation. Some land use activities—like land cultivation and intensive urban development—destroy nearly all woodland-wetland qualities, while other land use activities modify such areas in varying ways according to the intensity and duration of the stress. Different plant community types respond in different ways to disturbance, and some natural area types recover more quickly from disturbance.

[8] *Hydrophytes are plants that grow in water or wet habitats. Examples of hydrophytes in the Menomonee River watershed include cattails, yellow water crowfoot, and algae.*

Logging, grazing, land clearing, ditching, and tiling have all had a pronounced effect on the vegetation of the watershed. Logging has reduced large stands of timber, and grazing has eliminated wildlife food and habitat and has limited young tree growth. Land clearing for agricultural or urban development purposes in combination with construction of drainage works have either removed the natural vegetation from much of the watershed or have greatly altered the woodland and wetland areas. Another disturbance—Dutch elm disease—has had an especially ravaging effect in the Menomonee River Watershed.

Existing Conditions

In 1973 the Wisconsin Department of Natural Resources, Bureau of Research, under a cooperative agreement with the Regional Planning Commission, conducted an inventory of watershed woodland-wetland areas not yet protected by public ownership. This inventory was conducted to determine the current status of the watershed vegetal resources with respect to the number, size, and quality of the remaining unprotected woodland-wetland areas. The inventory was intended to determine the potential of the remaining woodland-wetland areas in preserving and improving the overall quality of the environment within the watershed.

Inventory Procedure: The inventory process was initiated by examining the files of the Wisconsin Scientific Areas Preservation Council and by polling known naturalists residing within the geographic area of the watershed. This initial reconnaissance was followed by examination of 1" = 400' scale SEWRPC aerial photographs and 1" = 2000' scale U. S. Geological Survey quadrangle maps to prepare a list of potential woodland-wetland areas of approximately 10 acres or more in size. The potential sites were then inspected in the field and a technical evaluation was completed for all sites except those of marginal value. Map 22 shows the locations of the 22 essentially unprotected woodlands and wetland areas identified in the survey and for which evaluations were completed. Selected information about each of these areas, including name, location, size, and description of vegetation types is set forth in Table 82. A summary of the remaining unprotected woodland-wetland areas by county is presented in Table 83.

Based on the field examination, one of the following four values ratings was assigned to each of the 22 sites:

1. High quality area—outstanding natural plant communities exhibiting minimal disturbance and containing desirable complementary natural features. The vegetal and other natural characteristics in combination with the size are such that the area is of state scientific area quality as a natural area. Parts of Bishops Woods in the City of Brookfield are typical of a high quality natural area.

2. Good quality area—good natural plant communities and other desirable natural features with some disturbance due to logging, grazing, or water level changes. The vegetal and other natural characteristics in combination with the size are such that the area is of regional or county significance as a natural area. The Tamarack Swamp in the Village of Menomonee Falls is typical of a good quality area.

3. Moderate quality area of areawide significance—the natural plant community has been significantly disturbed and few desirable complementary natural features remain. The most distinctive feature of woodland-wetland areas in this category is a riverine location and attendant continuous linear pattern on the landscape. Flood hazards and soils limitations in such areas mitigate against the use of these areas for urban development whereas the remaining vegetation and other natural features give these areas potential for parkway development. Woodland-wetland areas along the Little Menomonee River in the City of Mequon exemplify moderate quality areas having areawide parkway significance.

4. Moderate quality area of local significance—the vegetal and natural features are similar to the preceding quality category in that the natural plant community has been significantly disturbed. In contrast with the preceding category, however, these woodland-wetland sites are small and discontinuous and not necessarily located in riverine areas. The remaining natural vegetation and other natural features in these areas give them the potential for use as local natural areas and outdoor classrooms and to meet other open space needs of the urban environment. The Brookfield Swamp in the City of Brookfield is typical of a moderate quality area of local significance.

In addition to the criteria explicitly identified above, other supplementary factors were used in judging the overall value of each woodland-wetland area. These factors include the size of the area, a minimum size being considered necessary to protect the area's integrity; its degree of protection from surrounding land use which would act to degrade the natural area features; the diversity of plant community types and features existing in a continuous area; and an analysis of how prevalent the plant community type was in the presettlement landscape.

As a supplement to the value rating categorization, the woodland-wetland areas in the Menomonee River watershed were classified in accordance with the dominant vegetation types present in such areas. The following eight-category system was used to classify the existing vegetation:

1. Mesic upland hardwood forest as indicated by the presence of sugar maple, basswood, and other hardwoods which thrive in moderately wet areas.

2. Floodland hardwood forest as indicated by the presence of elm, silver maple, ash, and other hardwoods which thrive in seasonally flooded areas.

Table 82

UNPROTECTED WOODLAND-WETLAND AREAS IN THE MENOMONEE RIVER WATERSHED: 1973

Site Number	Site Name	Civil Division: County	Civil Division: City, Village, or Town	Ecologic Unit	Size (Acres)	Site Value Rating: High	Site Value Rating: Good	Site Value Rating: Moderate—of Regional Parkway Significance	Site Value Rating: Moderate—of Local Significance	Dominant Type of Vegetation[a]	Description, Problems, and Potential
1	Schoessow Woods	Washington	Village of Germantown	I	47	--	X	--	--	MUHF, FHF (Woodland)	Small areas of maple-beech upland forest alternating with lowland forest sites. Upland forest of 12-15 acres is extremely rich in species with these two rare and endangered ones: Gromwell (Lithospermum latifolium) and Golden Seal (Hydrastis canadensis). An outstanding diversity of tree species and herbs plus its state of preservation make the woods a logical candidate for preservation. Its small size and the Dutch elm disease in lowland sites detract from its overall value. It is highly threatened by a subdivision. Woods nearby to west are low quality. Area is one of three examples of this type in watershed.
2	Germantown Swamp	Washington	Village of Germantown	I	537	--	X	--	--	TSF, FHF (Wetland)	Lying in the headwater region of the Menomonee River, this wooded swamp is the largest tract of timber in the watershed. Like the majority of other timberlands in the region, it is predominantly low lying, and only considerable ditching would further reduce its size. At the north end on step topography can be found a remnant sugar maple-beech forest. In addition to the frequently seen trees of this region such as silver maple, American elm, green ash, black ash and basswood, uncommon trees like yellow birch and white cedar occur. Yellow birch is a codominant while white cedar, near its southern range limit in eastern Wisconsin, is occasional. There is considerable timber value in this swamp. The moderately rich understory is a mixture of northern and southern lowland forest types. Many elms have died; intense efforts at drainage have taken place at south and east ends. Although neither totally undisturbed nor greatly diverse, its large size and wild nature of its interior plus the unique timber quality and size make this area the best of its type in the watershed.
3	USH 41-45 Swamp	Washington	Village of Germantown	I	298	--	--	X	--	SSF, FHF (Wetland)	An extensive floodplain forest primarily wooded with silver maple, but also with green ash, black ash, and small American elm which have escaped Dutch elm disease. Due to disease, dissection by Highway 41-45, a logging history, and drainage, its natural area value is low and its commercial value minimal. Huge stumps attest to its former stature. Lying close to the Menomonee River, its prime values are for watershed protection and open space. A creek and other intermittent waterways enter the Menomonee River here.
4	Hoelz Swamp	Washington	Village of Germantown	I	171	--	--	X	--	SSF, FHF (Wetland)	A moderate quality natural area of swamp timber type in the headwaters region of the Menomonee River. There are several scattered small forests here where three intermittent streams enter the river. The northern portion is the best, containing silver maple-red maple, yellow birch, and some northern forest understory plants. Best use is maintenance of forest type for watershed protection.
5	Amy Bell Maples	Washington	Town of Richfield	I	38	--	--	--	X	MUHF (Woodland)	A second growth sugar maple forest on north and east slopes of morainal topography. Timber of little commercial value, but high scenic value. Site of geological interest although not unique in this aspect.
6	Wasaukee Road Marsh	Washington, Ozaukee	Village of Germantown City of Mequon	I	55	--	--	--	X	WLM, FHF (Wetland)	A low pocket between morainal deposits containing small ponds fed by intermittent drainages. Moderate wildlife habitat is in surrounding open marsh and some lowland forest. Area bisected by Wasaukee Road, from which waterfowl can be observed.
7	Kleinman-Salter Woods	Washington	Village of Germantown	I	92	--	--	X	--	SSF, FHF (Wetland)	Silver maple forest with some yellow birch, generally of poor natural area condition. Surrounded by cropland on three sides, shrub marsh to west.

Table 82 (continued)

Site Number	Site Name	Civil Division: County	Civil Division: City, Village, or Town	Ecologic Unit	Size (Acres)	Site Value Rating: High	Site Value Rating: Good	Site Value Rating: Moderate—of Regional Parkway Significance	Site Value Rating: Moderate—of Local Significance	Dominant Type of Vegetation[a]	Description, Problems, and Potential
8	Lake Park Woods	Washington	Village of Germantown	I	36	--	--	X	--	FHF (Wetland)	A disturbed silver maple remnant forest of importance for parkway considerations because two tributary, intermittent streams enter here.
9	Willow Creek Woods	Washington, Waukesha	Village of Germantown Village of Menomonee Falls	I, II[b]	107	--	--	X	--	SSF, FHF (Wetland)	Silver maple ash swamp forest with a brushy, open aspect and little natural area value.
10	Faber-Pribyl Woods	Washington	Village of Germantown	I	42	--	X	--	--	MUHF, FHF, WLM (Woodland)	Although partly developed along its west edge, this woods still exhibits characteristics of an old growth forest: mostly sugar maple with some beech and basswood all of 22-26 inches in diameter.
11	Tamarack Swamp	Waukesha	Village of Menomonee Falls	II	334	--	X	--	--	SSF, WLS, WLM, XUHF (Wetland)	An extensive shrub swamp dominated by speckled alder (Alnus rugosa) and winterberry (Ilex verticillata) with a variety of other shrubs including poison sumac (Rhus vernix), American currant (Ribes americanum), dog birch (Betula pumila), willow (Salix petiolaris), silky dogwood (Cornus obliqua), red osier dogwood (C. stolonifera) and round-leaved dogwood (C. rugosa). Marshy openings within the shrub swamp contain bluejoint grass (Calamagrostis canadensis), cattails (Typha latifolia), sedge (Carex lacustris), swamp milkweed (Asclepias incarnata) and mud plantain (Alisma trivale). Occasional small tamarack and black ash, which occur near the swamp edge, comprise the sparse tree layer at the south end, while northward the shrub swamp grades into an open forest. Water level fluctuations, fire and Dutch elm disease have influenced the area's composition. A solid waste site has encroached from CTH W. This is the only area of its type in the watershed and, although partially degraded, it is important for water quality protection, as a biotic sanctuary, and as an urban green space.
12	Held Maple Woods	Waukesha	Village of Menomonee Falls	II	37	--	X	--	--	XUHF, MUHF (Woodland)	An upland hardwood forest dominated by sugar maple and ironwood with an outstanding diversity of herbaceous plants. The occurrence of oaks and cherry, more common in drier forests, suggest a forest in transition to a maple-beech climax. North and west portions are pole size timber. Glacial topography and the presence of a small swamp forest at the south end add diversity. Logging has been the main intrusion in the past.
13	Potential Parkway	Waukesha	Village of Menomonee Falls Village of Butler	II	98	--	--	X	--	FHF (Wetland)	A two mile portion along the Menomonee River in Waukesha County. If established as parkway it would link the two portions of the Milwaukee County parkway and add additional protection to the watersheds, woodland, wetland, and wildlife resources.
14	Clark Woods	Waukesha	Village of Menomonee Falls Village of Butler	II	11	--	X	--	--	XUMF, MUHF (Woodland)	Upland mixed oak forest which occupies summit and north slope. Floodplain forest near river.
15	Theater Swamp	Waukesha	Village of Menomonee Falls	II	57	--	--	X	--	FHF, SSF, WLS (Wetland)	Degraded brush and floodplain forest.
16	Harley-Davidson Woods	Milwaukee	City of Wauwatosa	III	16	--	--	X	--	MUHF (Woodland)	Maple-basswood stand across the freeway from the Menomonee River parkway.

Table 82 (continued)

Site Number	Site Name	Civil Division: County	Civil Division: City, Village, or Town	Ecologic Unit	Size (Acres)	Site Value Rating: High	Site Value Rating: Good	Site Value Rating: Moderate—of Regional Parkway Significance	Site Value Rating: Moderate—of Local Significance	Dominant Type of Vegetation[a]	Description, Problems, and Potential
17	Grazed Forest Maple-Beech	Ozaukee	City of Mequon	V	55	--	--	--	X	MUHF (Woodland)	Upland forest type of sugar maple-beech with ash, elm, ironwood, and basswood. Although it has suffered heavy grazing, it has several spring wildflowers and offers protection to tributaries of the Little Menomonee River. Spring flowers noted are: wood anemone (Anemone quinquefolia), Jack-in-the-pulpit (Arisaema triphyllum), spring beauty (Claytonia virginiana), toothwort (Dentaria laciniata), fawn lily (Erythronium albidum), false mermaid (Floerkea proserpinacoides), geranium (Geranium maculatum), Virginia waterleaf (Hydrophyllum virginianum), false rue anemone (Isopyrum biternatum), phlox (phlox divaricata), mayapple (Podophyllum peltatum), bloodroot (Sanguinaria canadensis), and trillium (Trillium grandiflorum).
18	Disturbed Maple-Beech Forest	Ozaukee	City of Mequon	V	61	--	--	X	--	MUHF, FHF (Woodland)	Very disturbed upland forest on west-facing slope within 0.25 mile of Little Menomonee River. Cutting, grazing, and Dutch elm disease has reduced natural area value.
19	Floodplain Forest	Ozaukee	City of Mequon	V	208	--	--	X	--	FHF (Wetland)	Disturbed floodplain forest primarily of silver maple. Canopy open due to changing water levels and Dutch elm disease. Diversity low with numerous introduced species proliferating.
20	Bishops Woods[d]	Waukesha	City of Brookfield	VII	89	X[c]	--	--	--	MUHF, XUHF (Woodland)	Bishops Woods is the best woodland in the watershed. Composed of sugar maple and mixed upland hardwoods, the tract illustrates the dominant forest types in this region prior to settlement. Two rare and endangered wildflowers are present in its forest herbaceous layer.
21	Biwer Woods	Milwaukee	City of West Allis	VII	17	--	--	--	X	XUHF, MUHF, WLM (Woodland)	A small urban green area forested with upland hardwoods.
22	Brookfield Swamp	Waukesha	City of Brookfield Town of Brookfield	VII	359	--	--	--	X	FHF, SSF, MUHF, WLS, WLT (Wetland)	Degraded floodplain forest of lowland hardwoods like silver maple, green ash, elm. All three portions of the swamp are in headwaters region of Underwood Creek and were once part of the same lowland system. Intense ditching, encroachment and Dutch elm disease have lowered the natural area value drastically. Best use is for wildlife sanctuary-green space.
Totals:					2,765	1[c]	6	10	5	--	

[a] *Vegetation types are defined as follows:*

XUHF - xeric (dry) upland hardwood forest.
MUHF - mesic (moderately moist) upland hardwood forest.
FHF - floodland hardwood forest.
TSF - transitional swamp forest.
SSF - southern swamp forest.
WLT - wetland, tamarack swamp.
WLS - wetland, shrub swamp.
WLM - wetland, marsh.

Areas dominated by XUHF and MUHF are broadly categorized as woodlands and all remaining areas are broadly categorized as wetlands.

[b] *A 69 acre portion of Willow Creek Headwaters Forests lies in Ecologic Unit I and the remaining 38 acres in Ecologic Unit II.*

[c] *As a result of an office park development subsequent to the 1973 field survey of watershed woodlands and wetlands, Bishops Woods has been significantly disturbed and reduced in size. The remaining essentially undisturbed portions of Bishops Woods are now classified as being of good quality. Therefore, no high quality woodland-wetlands remain in the Menomonee River watershed.*

[d] *A small essentially virgin mesic upland hardwood forest, about seven acres, located north of Bishops Woods, was excluded from the watershed woodland-wetland inventory because of its size. This woodland was, however, examined by P. B. Whitford, Department of Botany, University of Wisconsin-Milwaukee in August 1967 and found to contain an unusual diversity of vegetation including about 14 different native trees, 14 native shrubs and vines, and over 40 native herbs. The woodland also provides habitat for a variety of birds and small mammals.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 83

UNPROTECTED WOODLAND-WETLAND AREAS IN THE MENOMONEE RIVER WATERSHED BY COUNTY: 1973

County	Value Rating								Totals			
	High		Good		Moderate—of Parkway Significance		Moderate—of Local Significance					
	Number of Sites	Acres	Number of Sites	Acres	Number of Sites	Acres	Number of Sites	Acres	Number of Sites	Percent of All Sites in Watershed	Area in Acres	Percent of Total Woodland-Wetland Areas in Watershed
Milwaukee . . .	0	0	0	0	1	16	1	17	2	9.1	33	1.2
Ozaukee[a]	0	0	0	0	2	269	1	55	3	13.6	324	11.7
Washington[a] . .	0	0	3	626	5	704	2	93	10	45.5	1,423	51.5
Waukesha[a] . . .	1	89	3	382	2	155	1	359	7	31.8	985	35.6
Total	1	89	6	1,008	10	1,144	5	524	22	100.0	2,765	100.0

[a] *Although small portions of Woodland-Wetland Sites 6 and 9 lie in Waukesha and Ozaukee County, respectively, each of these sites was assigned to Washington County for purposes of this table.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

3. Small lowland zones of tamarack swamp wetland.

4. Lowland zones of open marsh wetland containing cattails, sedges, and rushes.

5. Small lowland area of shrub swamp wetlands containing speckled alder, winterberry, and other similar shrubs.

6. Xeric upland hardwood forest as indicated by the presence of bur, white, and other oaks, which thrive in dry areas.

7. Transitional swamp forest elements dominated by the usual silver maples and elms with yellow birch and scattered white cedars as codominants.

8. Southern swamp forest elements, which include the silver maples, and willows, which thrive in old glacial lake beds and poorly drained low areas.

Xeric upland hardwood forests and mesic upland hardwood forests are the only two of the eight vegetal types falling within the broad category of woodlands. The remaining six vegetal types—floodland hardwood forest, transitional swamp forest, southern swamp forest, tamarack swamp wetland, shrub swamp wetland, and open marsh wetland—are more properly categorized as wetlands.

Inventory Findings: As indicated on Map 22 and in Table 82, 22 unprotected woodland-wetland areas of high, good, or moderate quality remain in the Menomonee River watershed. These areas range in size from about 11 acres to 537 acres, have an average size of 126 acres and an aggregate area of 2,765 acres, or only 3.2 percent of the watershed area. Thus, only small remnants exist of the extensive and diverse woodland-wetland areas that encompassed most of the watershed in presettlement times.

As indicated in Table 82, 10 of the 22 sites may be broadly categorized as woodlands whereas the remaining 12 sites are basically wetlands. The 10 woodland areas have an average size of only 40 acres, and encompass a combined area of 413 acres, or only 15 percent of the total area of the 22 inventoried woodland-wetland sites. The 12 wetland areas have an average size of about 215 acres—over five times the average size of the woodlands—and cover a total of 2,352 acres, or 85 percent of the total area of the 22 inventoried sites. In summary, then, although almost half of the remaining woodland-wetland sites may be broadly categorized as woodlands, the average size of the woodland sites is small relative to the average size of the wetland sites.

Essentially all of the remaining unprotected woodland-wetland areas in the watershed are located either in the headwater areas of the watershed or along the western edge and are therefore confined to Ozaukee, Washington, and Waukesha Counties. Based on vegetation classification, the floodland hardwood forest is the most dominant type of vegetation remaining in the watershed.

Most of the woodland-wetland areas are in the lowest two-value rating categories in that 15 of the 22 sites are classified as being of moderate quality. A total of six woodland-wetland areas—about one-fourth of the total—are in the good quality category, and these consist of the Germantown Swamp, Schoessow Woods, and the Faber-Pribyl Woods in the Village of Germantown; the Tamarack Swamp and Held Maple Woods in the Village of Menomonee Falls; and the Clark Woods in the Village of Butler. These six good quality sites have a total area of 1,008 acres, or only 1 percent of the watershed area. Only one high quality woodland-wetland area existed in the watershed at the time of the 1973 inventory: Bishops Woods in the City of Brookfield which had a total area of 89 acres. As mentioned earlier, an office park development subsequent to the 1973 field survey of watershed woodlands and wetlands has resulted in Bishops Woods being significantly disturbed and reduced in size. Since the remaining, essentially undisturbed portions of Bishops Woods are now classified as good quality, no high quality woodland-wetlands remain in the Menomonee River watershed.

Table 83 indicates that the Washington County portion of the watershed contains significantly more woodland-wetland areas than do the portions of watershed lying in the other three counties. About 45 percent of the remaining unprotected sites, comprising about 52 percent of the remaining unprotected woodland-wetland area, is located in the Washington County portion of the watershed. Waukesha County contains the second largest amount of unprotected woodland-wetland areas in that 32 percent of the sites comprising about 36 percent of the unprotected areas are located there. The general absence of unprotected woodland-wetland areas in the Milwaukee County portion of the Menomonee River watershed may be attributed to the Milwaukee County Park Commission's major long-term land acquisition program which has effectively protected the remaining good woodland-wetland areas. Only two small unprotected woodland-wetland areas were identified and evaluated in Milwaukee County, the moderate quality Harley-Davidson Forest which is contiguous with the Menomonee River Parkway in the City of Wauwatosa and Biwer Woods, also of moderate quality, located near the watershed boundary in West Allis.

Potential Values

The remaining woodland-wetland areas of the watershed are important to the maintenance of the overall quality of the environment in the watershed. Woodland-wetland areas have aesthetic, ecological, education and research, and recreational values.

Aesthetic Value: Woodland-wetland areas contribute to the scenic beauty of an area. This contribution is primarily a function of the location and of the variety and gradation of vegetation characteristic of the woodland-wetland sites. Woodland and wetlands lend contrast to the landscape, "soften" urban areas, provide needed open space and assist in avoiding monotony in the surroundings. Where any ruggedness exists in the topography, it is the wetlands which form the base level for the landscape.

The aesthetic value of woodland-wetland complexes in and near urban areas is enhanced by their potential to serve as effective visual barriers between conflicting urban land uses such as a commercial area and a residential neighborhood. Furthermore, when dense, tall woodland-wetland areas lie between a residential neighborhood and a source of noise—such as a freeway—the trees, shrubs, and other vegetation will provide a significant amount of sound attenuation. For example, a dense vegetal belt as narrow as 100 feet located between a freeway and a residential neighborhood may, by absorption and diffusion, reduce sound intensity within the residential area by up to one-half of the level that would exist in the absence of the vegetation.[9,10]

Unpleasant sights and objectionable noise levels can be minimized in urban areas by land use design that incorporates proper juxtaposition of the source of the problem, the area to be protected, and the woodland-wetland areas. Such land use design must recognize, of course, that while there may be many options regarding the ultimate position of sources and of the areas to be protected, the woodland-wetland sites constitute an essentially fixed natural resource and must therefore be identified and protected prior to development.

A potentially troublesome problem of an aesthetic nature which may be associated with wetland are odors which occasionally occur as the result of one of two basic processes. One of these processes is anaerobic decomposition of organic deposits, which yields the gases hydrogen sulfide and ammonia, both of which have strong characteristic odors. Under normal circumstances, water bacteria oxidize these gases so that they do not escape into the air except during periods of drought or after drainage. The second source of odors is the decomposition of algae, which may abound if the wetland receives excessive enrichment, as from field or lawn fertilizers. Typically, mid-to-late summer is the most troublesome period for the production of wetland odors due to high temperatures, lowered water levels, and accumulated vegetative growth.

Ecological Value: Man is one element in the ecological web and, as such, can affect and may be affected by, both the physical environment and other members of the biological community. Woodland-wetland areas are important to the watershed ecosystem since they contain a relatively high proportion of the natural, physical, and biological features of the environment which interact to provide a major part of the essentials for a functional ecosystem. While the human population of a watershed could undoubtedly exist even if all the natural values of these areas were eliminated by uncontrolled urbanization, the quality of the watershed ecosystem would be significantly degraded. Protection of some of the remaining woodland-wetland areas will serve various ecological functions directly affecting the overall quality of life including: protection of the biologically most produc-

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[9] *D. I. Cook and D. F. Van Haverbeke, "Trees, Shrubs and Landforms for Noise Control,"* Journal of Soil and Water Conservation, *November-December 1972.*

[10] *R. E. Leonard, "Effects of Trees and Forest in Noise Abatement,"* Trees and Forests in an Urbanizing Environment, *Cooperative Extension Service of the University of Massachusetts, Amherst, March 1971.*

tive areas of a watershed, provision of continuous wildlife range, and maintenance of water quality enhancement processes.

Woodlands and wetlands are the primary habitat for game animals and fish and, as such, must be preserved if a diverse wildlife population is to survive. Woodland-wetland areas are also an important habitat for beneficial organisms such as pollinating insects and the micro-flora and fauna that transform organic materials to basic elements. Riverine areas are also biologically productive in the sense that they provide diverse and unique flora and fauna. Preservation of some woodland-wetland areas in natural open space facilitates realization of the educational, scientific, and aesthetic values attendant to that species diversity and uniqueness.

Diversity in the biota is more than just a pleasant "extra"; it is also essential to maintaining an ecological balance. When a community is fully stocked, there are more organisms available to create a more balanced predator-prey relationship; and this condition helps prevent outbreaks or irruptions of pests or nuisances. Diversity is the original ecological control that must increasingly be returned to as a substitute for chemical control methods if the overall quality of the environment for life is to be preserved. When man forces biological simplification on the native biota, this reduction in diversity permits irruptive situations to develop. From a biological stand-point, the loss of diversity as woodlands and wetlands are destroyed is probably the greatest loss of all the amenities.

Continuous corridors of open space riverine lands physically linking urban natural areas with distant larger rural wildlife habitat areas will contribute to the maintenance of wildlife in the urban areas. Reservation of open space "islands" within predominantly urban areas is not sufficient to assure populations of self-sustaining, diverse resident wildlife species. It is necessary to maintain a continuous range between the rural wildlife habitat and the urban open space areas which may include semi-natural areas such as urban woodlots, small parks, and even large homesites. Most of the remaining woodland-wetland sites in the watershed are concentrated in linear patterns along the watershed stream system in the Ozaukee, Washington, and Waukesha portions of the watershed. If these sites are protected and linked together by riverine lands that are also maintained in a natural open state, the net effect will be to provide continuous corridors of open space lands extending from the intensely urbanized areas of the watershed into the rural areas.

Wetlands also help to protect the water quality of streams and lakes. Undisturbed wetlands serve as nutrient and sediment traps. Drainage of wetlands not only eliminates this trapping function but may also be expected to precipitate the sudden release of large amounts of accumulated nutrients.[11]

[11] *G. F. Lee, E. Bentley, and R. Amundson, "Effect of Marshes on Water Quality," Presented to the International Ecological Association, Leningrad, Russia, 1971.*

Riverine area woodland-wetland areas have a demonstrated effect on the quality of fish habitat. The partial vegetal canopy provided along natural streams by woodland-wetland areas intercepts solar radiation thereby helping to maintain summer water temperatures at the lower levels conducive to the maintenance of a healthy fishery. Removal of large amounts of brush and trees from the banks of small headwater streams will result in a very signficant change in temperature characteristics including increased diurnal fluctuations and overall higher temperatures.[12]

Wetland areas may also have some minor negative effects on water quality. Drainage from wetlands sometimes contributes water low in dissolved oxygen and high in iron and organic material and in color. These undesirable water quality impacts are, however, offset on an annual basis by the filtering capability of wetlands as discussed above.

Another potentially troublesome biological feature of wetlands is that they may serve as habitat for some insect pests. The major undesirable group of insects associated with wetlands is the mosquito, although wetlands contribute less to the mosquito problem than is commonly believed. There are many species of mosquitoes, only some of which bite man; and mosquitoes are produced in large numbers in areas other than wetlands. Street gutters, eave troughs, tin cans and other containers, temporary stands of water in fields, woods, and tree cavities may all "come to life" from previously deposited eggs after snowmelt or heavy rains. Some of the hardest biting species have life cycles of only a few days. Many of the larger wetland areas, if a well diversified biota is present, generate small numbers of mosquitoes relative to stagnant temporary bodies of water exhibiting an imbalanced ecologic community. Locally, black flies and deer flies may create nuisance situations.

Education and Research Function: In addition to serving a variety of ecological functions, portions of protected woodlands and wetlands may be used to educate the public about those ecological functions and to provide scientists with the opportunity for ecological research. In an undisturbed state, these natural areas are highly prized by educators, naturalists, and wildlife managers, for such areas are becoming increasingly scarce, while their values are becoming more widely accepted and understood. Education and research activities may be accomplished by establishing interpretive nature centers, natural area reserves, and restricted use research areas either within or contiguous to woodland-wetland and related natural areas. The educational use and potential use of woodland-wetland areas is effectively illustrated by Milwaukee County Park System parkways which make a variety of vegetal environments readily accessible to the urban populations. Portions of the parkways have been used as outdoor classrooms, and considerable

[12] *G. W. Brown and J. T. Krygier, "Effects of Clear-Cutting on Stream Temperature," Water Resources Research, Volume 6, No. 4, August 1970.*

potential exists for increasing such activities in Milwaukee County and for extending such functions into Ozaukee, Washington, and Waukesha Counties.

Recreation-Related Value: The woodland-wetland areas remaining in the Menomonee River watershed generally cannot, because of their small size and sensitivity to external disturbances, provide a basis for intensive recreational activities such as field sports, skiing, and tobogganing. These natural areas can, however, provide a basis for more passive recreational pastimes such as hiking, picnicking, bird watching, nature study, and pleasure driving. Carefully selected portions of these areas may be developed for active recreational activities, the value of which will be enhanced by the close proximity of natural areas. This approach is illustrated by the Milwaukee County Park Commission parkway system where certain areas are developed for active recreational activities such as field sports and group picnicking while adjacent areas have been retained in essentially natural conditions.

Relationship of Existing Woodlands and Wetlands to Watershed Development Objectives and Standards

Land Use Development Objective 2 as set forth in Chapter 2 of Volume 2 of this report, specifies a spatial distribution of the various land uses which will result in the protection, wise use, and development of the natural resources of the Region. Several of the quantitative standards supporting this objective pertain explicitly to woodlands; one standard in particular relates to woodlands within the context of a watershed. The woodlands remaining in the watershed fall far short of meeting this standard which specifies that at least 10 percent of the land area of each watershed within the Region should be devoted to woodlands. Based on woodland-wetland data presented in Table 82, approximately 413 acres of unprotected woodland still remain in the Menomonee River watershed. As described in Chapter III of this volume, the watershed contains 6,138 acres of publicly or privately owned park, outdoor recreation, and related open space sites that were generally excluded from the woodland inventory. The areal extent of woodlands within these sites is unknown. If half the public park area, or about 3,000 acres, were devoted to woodlands, a total of 3,400 acres would exist within the watershed. This would be less than 40 percent of the total woodland area required by the woodland standard. The fact that the remnant woodlands in the Menomonee River watershed fall far short of meeting the recommended standard should give added impetus to the protection of those remnant areas. The task within the watershed is not one of meeting the minimum woodland standard but of minimizing the deficit.

Another one of the standards supporting Land Use Development Objective 2 pertains explicitly to wetlands. This standard specifies that all wetland areas adjacent to streams and lakes, all wetland areas having special wildlife and other natural values, and all wetlands having an area in excess of 50 acres should not be allocated to any urban development except for limited recreational use and should not be drained or filled. The 12 remaining wetland sites in the Menomonee River watershed should be protected in accordance with this standard since each of the 12 sites covers an area in excess of 50 acres and most of the sites are adjacent to perennial streams and important components of the remaining wildlife habitats of the watershed.

WILDLIFE AND WILDLIFE HABITAT

Wildlife are desirable in urban and urbanizing areas such as the Menomonee River watershed because of their aesthetic values, their importance in the ecological system, their value for education and research, and their enhancement of certain recreational activities. The location, extent, and quality of wildlife habitat areas and the type of wildlife characteristic of those areas are, therefore, important determinants of the overall quality of the environment in the watershed. The Menomonee River watershed planning program included an inventory and analysis of wildlife and wildlife habitat to provide the data and information needed to plan for the wise use of what remains of this resource.

Historic and Existing Conditions

The complete spectrum of wildlife species originally native to the watershed have, along with their habitat, undergone tremendous alteration since settlement of the watershed by Europeans. The change is the direct result of an extreme conversion of the basic environment, beginning with clearing of forests and prairie and the drainage of wetlands and ending with extensive urbanization. This process, which began in the early nineteenth century when European settlers began to develop the watershed, is still operative today. Successive cultural practices, both rural and urban, have been superimposed on the overall land use changes and have also affected the wildlife and wildlife habitat in the watershed. In agricultural areas, these cultural practices include land drainage by ditching and tiling and the expanding use of fertilizers and pesticides. Examples of urban area cultural practices that affect wilidlife and their habitats are use of fertilizers and pesticides, road salting, heavy traffic which produces disruptive noise levels, and damaging air pollution.

Many of these land use changes and the cultural activity subsequently superimposed on those changes have proceeded with little explicit concern for wildlife and their habitat. The resiliency of wildlife to such impacts is truly remarkable, but a tremendous toll has been taken. Inexorably the minimum life requirements have disappeared over much of the watershed and, as a result, only remnants remain, to continue a precarious existence. The wildlife and wildlife habitat loss is only part of a much greater loss of diversity that is characteristic of natural communities.

The Wisconsin Department of Natural Resources, under a cooperative agreement with the Regional Planning Commission, conducted an inventory of watershed wildlife habitat areas in 1973. This inventory was intended to provide a determination of the current status of the watershed wildlife resources with respect to the number, size, and quality of all remaining wildlife habitat areas and the type and variety of wildlife characteristic of those habitats. The inventory also was designed to ascertain the potential role of wildlife and wildlife habitat in sustaining and improving the overall quality of the environment in the watershed.

Inventory Procedure: The inventory effort was initiated by polling naturalists within the geographic area of the watershed and by examining 1" = 400' scale SEWRPC aerial photographs and 1" = 2000' scale U. S. Geological Survey quadrangle maps. The inventory procedure concentrated on wildlife habitat sites that were 10 acres or more in size but some small sites were included if they appeared to have the potential to significantly influence local wildlife. The sites identified in this initial reconnaissance were then examined in the field and technical evaluations were completed for all sites. Map 24 shows the locations of 100 wildlife habitats that were identified in the Menomonee River watershed as a result of the above inventory process. Selected information about each wildlife habitat area such as location, size range, value rating, characteristic wildlife and threat classification is set forth in Table 84, and a summary of wildlife habitat areas by county is presented in Table 85.

The precise areal extent of any particular wildlife habitat is indeterminable. While the wildlife within a given habitat may concentrate most of their activities in a woodland or wetland area that constitutes the principal element in the habitat and can be delineated with some precision, their normal range may extend into contiguous surrounding agricultural, open space, and even residential areas, the extent of which can not be precisely delineated. For this reason, the size of each of the 100 wildlife habitats in Table 84 is specified by a size range.

Based primarily on the field evaluation, one of the following four value ratings was assigned to each of the 100 habitats in order to reflect its existing condition:

1. High quality area—generally undisturbed and having a high plant and animal diversity. The Tamarack Swamp on the watershed divide in the Village of Menomonee Falls typifies a high quality wildlife habitat area.

2. Good quality area—some disturbance but still retaining a good plant and animal diversity. Portions of Franklin Wirth Park in the City of Brookfield and the contiguous open lands to the northwest exemplify a good quality wildlife habitat area.

3. Moderate quality area—considerable disturbance and exhibiting low plant and animal diversity. The riverine area along most of the Little Menomonee River in Ozaukee and Milwaukee Counties is typical of a wildlife habitat area of moderate quality.

4. Low quality area—a remnant or markedly deteriorated former wildlife habitat area. Scattered small areas along the eastern edge of the Village of Menomonee Falls typify this type of wildlife habitat area.

Other factors considered in assigning value ratings to some wildlife habitat areas include size (certain species have minimum spatial requirements), the presence of protective vegetation, and the proximity of streams, ponds, and other wildlife habitats.

In addition to the value rating categorization, all the wildlife habitats in the Menomonee River watershed were classified according to the wildlife type to which the habitats were suited. Thus the wildlife classifications used on Map 24 and Table 84 are intended to indicate the type of wildlife that would be characteristic of a particular site. It does not necessarily follow that those wildlife types were observed in the site during the field work or that they actually reside in the habitat. A threat classification was also provided for each of the 100 wildlife habitats to identify those wildlife areas apparently vulnerable to further deterioration.

Inventory Findings: *Habitat:* As indicated on Map 24 and in Tables 84 and 85, 100 wildlife habitat areas were identified as remaining in the Menomonee River watershed. With respect to size, most of these habitats are small in that 84 sites are less than 160 acres in size. The second most prevalent size is the 160 acre to 320 acre category which includes 13 sites. The other wildlife habitat sites are distributed as follows: two sites in the 321-acre to 480-acre size range, and only one site in the 481-acre to 640-acre size range. Thus, although a considerable number of wildlife habitat sites still remain in the Menomonee River watershed, these sites are generally small, and are only remnants of the extensive and diverse wildlife habitat areas that once were present in the watershed.

Only three high quality wildlife habitat areas still exist in the watershed: the Tamarack Swamp in the Village of Menomonee Falls, a small site known as Held Maple Woods in the northwest corner of Menomonee Falls, and the large woodland-wetland area known as the Germantown Swamp in the northeast corner of the Village of Germantown. These three high quality areas are all located in the upper third of the watershed.

Of the 22 good quality wildlife habitats in the watershed, 19 are concentrated in the upper portions of the watershed. Notable exceptions are the three relatively large sites located in the middle of the watershed within the City of Brookfield.

With respect to the four value ratings—high, good, moderate, and low—the moderate category is the most common in that 63 sites, or 63 percent of all the sites, were determined to be of moderate quality. The moderate value sites are also distributed more uniformly over the watershed than are sites in the other three categories. As shown on Map 24, the moderate value wilidlife habitat areas are closely related to the riverine areas and therefore tend to be continuous and linear. Most of the Milwaukee County Park System parkways are in the moderate value category.

There are 12 low quality wildlife habitat areas in the Menomonee River watershed. These sites, which comprise 12 percent of the total number of sites, are small—all are

Table 84

WILDLIFE HABITAT AREAS IN THE MENOMONEE RIVER WATERSHED: 1973

Site Number	Civil Division		Ecologic Unit	Acreage Range					Site Value Rating				Characteristic Wildlife							Threat Classification				
	County	Township		Less than 160	160 to 320	321 to 480	481 to 640	640 to 800	High	Good	Moderate	Low	Waterfowl	Muskrat	Pheasant	Deer	Squirrel	Songbirds	Mixed	Advancing Development	Urban Activity in Close Proximity	Commercial Activity in Close Proximity	Industrial Activity in Close Proximity	Filling Occurring
1	Washington	Richfield	I	X						X			X		X		X			X				
2	Washington	Richfield	I	X							X				X			X						
3	Washington	Richfield	I	X							X				X									
4	Washington	Richfield	I	X							X							X						
5	Washington	Richfield	I	X							X						X	X						
6	Washington	Germantown	I				X		X							X								
7	Washington	Germantown	I	X						X							X			X				
8	Washington	Germantown	I	X						X					X		X							
9	Washington	Germantown	I	X						X							X		X					
10	Washington	Germantown	I	X						X					X			X						
11	Washington	Germantown	I	X						X			X					X		X				
12	Washington	Germantown	I		X					X					X									
13	Washington	Germantown	I			X				X									X					
14	Washington	Germantown	I	X							X						X	X						
15	Washington	Germantown	I	X							X								X					
16	Washington	Germantown	I	X							X				X			X						
17	Washington	Germantown	I	X							X								X					
18	Washington	Germantown	I	X							X								X					
19	Washington	Germantown	I	X							X								X					
20	Washington	Germantown	I	X							X								X					
21	Washington	Germantown	I	X							X						X		X					
22	Washington	Germantown	I	X							X								X	X				
23	Washington	Germantown	I	X							X								X	X				
24	Washington	Germantown	I	X							X		X		X				X					
25	Washington	Germantown	I	X							X								X					
26	Washington	Germantown	I		X						X								X					
27	Washington	Germantown	I	X							X					X	X		X	X				
28	Washington	Germantown	I	X							X		X		X				X					
29	Washinton	Germantown	I	X							X								X					
30	Washington	Germantown	I	X							X								X					
31	Washington	Germantown	I	X							X								X					
32	Washington	Germantown	I	X							X		X											
33	Washington	Germantown	I	X							X								X					
34	Washington	Germantown	I	X							X						X							
35	Washington	Germantown	I	X							X						X							
36	Washington	Germantown	I	X								X						X						
37	Washington	Germantown	I	X								X							X					
38	Washington	Germantown	I	X								X							X					
39	Washington	Germantown	I	X								X						X						
40	Washington	Germantown	I	X								X						X						
41	Ozaukee	Mequon	I	X						X									X					
42	Ozaukee	Mequon	I	X						X						X			X					

Table 84 (continued)

Site Number	Civil Division		Ecologic Unit	Acreage Range					Site Value Rating				Characteristic Wildlife							Threat Classification				
	County	Township		Less than 160	160 to 320	321 to 480	481 to 640	640 to 800	High	Good	Moderate	Low	Waterfowl	Muskrat	Pheasant	Deer	Squirrel	Songbirds	Mixed	Advancing Development	Urban Activity in Close Proximity	Commercial Activity in Close Proximity	Industrial Activity Industrial Proximity	Filling Occurring
43	Ozaukee	Mequon	I	X						X							X							
44	Ozaukee	Mequon	I	X						X			X			X								
45	Ozaukee	Mequon	I	X							X		X				X							
46	Waukesha	Menomonee Falls	II	X					X								X		X					
47	Waukesha	Menomonee Falls	II			X			X							X	X		X					
48	Waukesha	Menomonee Falls	II	X							X				X				X	X				
49	Waukesha	Menomonee Falls	II	X							X								X		X			
50	Waukesha	Menomonee Falls	II	X							X								X					
51	Waukesha	Menomonee Falls	II	X							X								X		X			
52	Waukesha	Menomonee Falls	II		X						X								X					
53	Waukesha	Menomonee Falls	II		X						X							X	X	X			X	
54	Waukesha	Menomonee Falls	II	X							X								X					
55	Waukesha	Menomonee Falls	II		X						X				X				X	X				
56	Waukesha	Menomonee Falls	II	X							X						X		X	X				
57	Waukesha	Menomonee Falls	II	X							X								X	X				
58	Waukesha	Menomonee Falls	II	X								X	X											
59	Waukesha	Menomonee Falls	II	X								X	X											
60	Waukesha	Menomonee Falls	II	X								X	X											X
61	Waukesha	Menomonee Falls	II	X								X						X						
62	Waukesha	Menomonee Falls	II	X								X						X						
63	Waukesha	Menomonee Falls	II	X								X						X						
64	Milwaukee	Granville	II	X							X							X	X			X		
65	Milwaukee	Granville	II	X							X								X					
66	Milwaukee	Granville	II	X							X								X					
67	Waukesha	Brookfield	II		X						X				X				X					
68	Milwaukee	Wauwatosa West	III	X						X									X		X			

Table 84 (continued)

Site Number	Civil Division: County	Civil Division: Township	Ecologic Unit	Acreage Range: Less than 160	Acreage Range: 160 to 320	Acreage Range: 321 to 480	Acreage Range: 481 to 640	Acreage Range: 640 to 800	Site Value Rating: High	Site Value Rating: Good	Site Value Rating: Moderate	Site Value Rating: Low	Characteristic Wildlife: Waterfowl	Characteristic Wildlife: Muskrat	Characteristic Wildlife: Pheasant	Characteristic Wildlife: Deer	Characteristic Wildlife: Squirrel	Characteristic Wildlife: Songbirds	Characteristic Wildlife: Mixed	Threat Classification: Advancing Development	Threat Classification: Urban Activity in Close Proximity	Threat Classification: Commercial Activity in Close Proximity	Threat Classification: Industrial Activity Industrial Proximity	Threat Classification: Filling Occurring
69	Milwaukee	Wauwatosa West	III	X							X								X		X			
70	Milwaukee	Wauwatosa West	III		X						X								X		X			
71	Milwaukee	Wauwatosa West	III	X							X								X		X			
72	Ozaukee	Mequon	V	X						X							X							
73	Ozaukee	Mequon	V	X						X							X							
74	Ozaukee	Mequon	V	X						X					X				X					
75	Ozaukee	Mequon	V	X						X								X						
76	Ozaukee	Mequon	V	X						X							X							
77	Ozaukee	Mequon	V	X							X						X							
78	Ozaukee	Mequon	V	X							X				X	X	X			X				
79	Ozaukee	Mequon	V		X						X						X		X					
80	Ozaukee	Mequon	V	X							X		X		X									
81	Ozaukee	Mequon	V		X						X		X	X	X									
82	Milwaukee	Granville	VI		X					X			X	X										
83	Milwaukee	Granville	VI	X							X						X	X						
84	Milwaukee	Granville	VI	X							X								X					
85	Milwaukee	Granville	VI	X							X							X						
86	Milwaukee	Granville	VI	X							X							X		X				
87	Milwaukee	Granville	VI	X							X							X	X	X				
88	Milwaukee	Granville	VI	X							X							X	X	X				
89	Milwaukee	Granville	VI	X							X							X	X	X		X		
90	Waukesha	Brookfield	VII		X					X								X	X					
91	Waukesha	Brookfield	VII		X					X								X	X					
92	Waukesha	Brookfield	VII		X					X							X	X	X	X				
93	Waukesha	Brookfield	VII	X							X				X				X					
94	Waukesha	Brookfield	VII	X							X						X		X		X			
95	Waukesha	Brookfield	VII	X							X								X		X			
96	Waukesha	Brookfield	VII	X							X								X	X				
97	Waukesha	Brookfield	VII	X								X							X	X				
98	Milwaukee	Wauwatosa West	VII	X							X								X		X			
99	Milwaukee	Wauwatosa West	VII	X							X								X		X			
100	Milwaukee	Wauwatosa West	VIII	X							X								X		X			

NOTE: The precise areal extent of a given wildlife habitat is indeterminable and therefore the size of each habitat is specified by one of the following acreage ranges: 0-160, 161-320, 321-480, 481-640, and 640-800.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 85

WILDLIFE HABITAT AREAS IN THE MENOMONEE RIVER WATERSHED BY COUNTY: 1973

County	Value Rating								Totals			
	High		Good		Moderate		Low					
	Number of Sites	Nominal Acreage[a]	Number of Sites	Nominal Acreage[a]	Number of Sites	Nominal Acreage[a]	Number of Sites	Nominal Acreage[a]	Number of Sites	Percent of of All Sites in Watershed	Nominal Acreage[a]	Percent of Total Habitat Area in Watershed
Milwaukee . . .	0	0	2	320	16	1,440	0	0	18	18	1,760	15.7
Ozaukee	0	0	9	720	6	800	0	0	15	15	1,520	13.6
Washington . .	1	560	8	1,120	26	2,240	5	400	40	40	4,320	38.6
Waukesha . . .	2	480	3	720	15	1,840	7	560	27	27	3,600	32.1
Total	3	1,040	22	2,880	63	6,320	12	960	100	100	11,200	100

[a] *The precise areal extent of a given wildlife habitat is indeterminable and therefore the size of each habitat is specified by one of the following acreage ranges: 0-160, 161-320, 321-480, 481-640, and 640-800. For purposes of acreage totals in this table, the size of each wildlife habitat area was taken as the midpoint in its size range. For example, a habitat area in the 161-320 acreage range was assigned a nominal area of 240 acres.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

less than 160 acres in size—and they are scattered over the Ozaukee, Washington, and Waukesha County portions of the watershed.

Wildlife: while the above section emphasized the quantity and quality of wildlife habitat that still remains in the Menomonee River watershed, the following discussion explicitly treats the wildlife of the watershed. The watershed's wildlife population consists of fish, amphibians and reptiles, birds and mammals. Each of these classes within the animal kingdom is discussed below with the exception of the fish which were discussed earlier in this chapter.

Amphibians and Reptiles: Although often unseen and unheard, amphibians and reptiles are vital components of the ecologic system of an environmental unit like the Menomonee River watershed. Examples of amphibians native to the watershed include frogs, toads, salamanders, and newts. Turtles and snakes are examples of reptiles common to the Menomonee River watershed.

Although a field inventory of amphibians and reptiles was not conducted in the Menomonee River watershed, it was possible by using existing information, such as the records of the City of Milwaukee Public Museum, and by polling naturalists to complete a list of amphibians and reptiles likely to be found in the watershed under existing conditions. The technique used by the Wisconsin Department of Natural Resources involved taking records of amphibians and reptiles for the four counties comprising the Menomonee River watershed, associating the listed amphibians and reptiles with their habitats, examining historic and existing habitats in the watershed and projecting the appropriate amphibians and reptiles into the watershed. The net effect of this technique is an understanding of what species were once present in the basin, which species are most likely to be present under existing conditions and which species can be expected to be lost as urbanization proceeds. Table 86 presents a summary of the amphibians and reptiles likely to exist in the Menomonee River watershed under present conditions and identifies those species most sensitive to urbanization.

Most amphibians and reptiles have definite habitat requirements which are adversely affected by advancing urban development. One of the major deterrents to maintaining amphibians in a changing environment is the destruction of breeding ponds. Frogs and salamanders often return to the same site year after year, even if the pond if not there, in which case they cannot breed. When an area is being filled and developed and some ponds are to be saved, they must be selectively saved or they are of no value in maintaining amphibian habitats. Toads are somewhat of an exception with respect to habitat requirements in that they are very flexible with respect to their environmental needs and can exist in spite of increasing urbanization.

Another major consideration for the preservation of both amphibians and reptiles is migration routes. Many species annually traverse a mile or more from wintering sites to breeding sites to summer foraging grounds. The same pathways are used each year. Certain amphibians and reptiles are particularly susceptible to changes in food sources brought about by urbanization. The bull snake and milk snake, for example, are very likely to be lost because of the reduction of rodents, their potential prey.

Birds: A large number of birds, ranging in size from large gamebirds to small songbirds, are found in the Menomonee River watershed. Table 87 of this report is a list of 232 birds that are known to exist or might be expected to occur in the watershed. Each bird is classifed by whether it breeds within the watershed, visits the watershed during the annual migration period, or might be observed on rare occasions. A discussion of the species of greatest importance in the watershed is presented below.

Game birds which are found in the watershed include the pheasant, Hungarian (gray) partridge, woodcock, jacksnipe, rails, dabbling ducks, diving ducks, coot, and some geese. Pheasant and Hungarian partridge are upland game birds and provide some bird hunting. Although the watershed lies within the "Mississippi Flyway," waterfowl hunting opportunity is now rather limited because of habitat deterioration.

Table 86

AMPHIBIANS AND REPTILES LIKELY TO EXIST IN THE MENOMONEE RIVER WATERSHED: 1974

Amphibians

Common Name	Species Reduced or Dispersed With Full Watershed Urbanization	Species Lost With Full Watershed Urbanization
Blue Spotted Salamander		X
Spotted Salamander		X
Tiger Salamander	X	
Eastern Newt	X	
Red-Backed Salamander		X
Mudpuppy	X	
Bullfrog		X
Green Frog	X	
Leopard Frog		X
Pickerel Frog		X
Wood Frog		X
American Toad	X	
Cricket Frog	X	
Spring Peeper		X
Gray Treefrog		X
Chorus Frog	X	

Reptiles

Common Name	Species Reduced or Dispersed With Full Watershed Urbanization	Species Lost With Full Watershed Urbanization
Snapping Turtle	X	
Musk Turtle (Stinkpot)	X	
True Map Turtle		X
Midland Painted Turtle	X	
Blandings Turtle		X
Eastern Spiny Softshell Turtle		X
Five-Lined Skink		X
Northern Water Snake	X	
Queen Snake		X
Northern Brown Snake	X	
Red-Bellied Snake	X	
Eastern Garter Snake	X	
Prairie (Plains) Garter Snake	X	
Butler's Garter Snake	X	
Hog-Nosed Snake		X
Eastern (northern) Ring-necked Snake		X
Bull Snake		X
Eastern Milk Snake		X

Source: Wisconsin Department of Natural Resources and University of Wisconsin.

The fall pheasant population within the watershed is very irregularly distributed but fair populations live in the larger existing habitats. The pheasant population is supplemented annually by the release of state-propagated birds, consisting largely of cocks, through local cooperator clubs and on public hunting grounds. In areas actively hunted adjacent to the watershed, harvests may reach 20 or more cocks per square mile without the supplement of released birds but similar harvests are not expected in the watershed due to limitations on hunting. Wintering flocks of birds may encompass large flocks that could reach 50 to 100 birds. Flocks of that size require good cover and feed interspersed with waste grain such as corn available from farming operations. Supplemental feeding of such groups will greatly aid them during severe winters but pheasant populations can be a nuisance to the gardener and the farmer.

The Hungarian (gray) partridge, although less important than the pheasant as a game bird, is abundant enough to be of interest to the public and sportsmen alike. The "Hun" is a coveying bird sometimes seen in larger flocks in winter. The game bird requires larger expanses of rural area than are provided by much of the watershed. A flock will roam over several farms over a season although it may subsist in much smaller areas for shorter periods. Numbers often exceed pheasant densities with several coveys occurring in a square mile in suitable areas not greatly distant from the watershed.

Ruffed grouse may occur sparsely in some wooded locations in the watershed. While ruffed grouse numbers generally fluctuate widely in Wisconsin, high numbers do not exist anywhere in southeastern Wisconsin and little ruffed grouse activity can be expected in the Menomonee River watershed.

The bobwhite quail have been virtually eliminated within the watershed; however, in a few areas the range potential may exist for their reintroduction. Very small populations generally exist in this part of the state so the potential for this bird is very low in the watershed.

There is a significant population of waterfowl in the watershed, especially the mallard and the teal. Larger numbers move through in migration when most of the regional species may be present except those requiring large lakes such as loons and scoters. Other species of water-based birds within the watershed include herons, sandpipers, gulls, plovers, and terns.

Because of the admixture of lowland and upland forest, meadows, and agricultural lands along with favorable warm-season climate, the watershed supports many other species of birds. Hawks and owls function as major rodent predators within the ecosystem. Swallows, whip-poor-wills, woodpeckers, nuthatches, and flycatchers, as well as several other species of birds found in the watershed, serve as major insect predators. In addition to their ecological roles, birds such as robins, orioles, cardinals, kingfishers, and mourning doves serve as subjects for birdwatchers and photographers.

Table 87

BIRDS IN THE MENOMONEE RIVER WATERSHED

Birds	Migrant	Breeder	Rare	Birds	Migrant	Breeder	Rare
Horned Grebe	M			Black-Bellied Plover	M		
Pied-Billed Grebe		B		Ruddy Turnstone	M		
Double-Crested Cormorant	M			Woodcock		B	
Great Blue Heron		B		Common Snipe	M		
Green Heron		B		Upland Sandpiper			R
Great Egret	M			Spotted Sandpiper		B	
Black-Crowned Night Heron		B		Solitary Sandpiper	M		
Least Bittern		B		Greater Yellowlegs	M		
American Bittern		B		Lesser Yellowlegs	M		
Whistling Swan	M			Pectoral Sandpiper	M		
Canada Goose	M			White-Rumped Sandpiper	M		
Snow Goose	M			Baird's Sandpiper	M		
Mallard		B		Least Sandpiper	M		
Black Duck		B		Dunlin	M		
Gadwall	M			Short-Billed Dowitcher	M		
Pintail		B		Long-Billed Dowitcher	M		
Green-Winged Teal		B		Stilt Sandpiper	M		
Blue-Winged Teal		B		Semipalmated Sandpiper	M		
American Wigeon (Baldpate)	M			Sanderling	M		
Northern Shoveler		B		Wilson's Phalarope			R
Wood Duck		B		Northern Phalarope	M		
Redhead	M			Herring Gull	M		
Ring-Necked Duck	M			Ring-Billed Gull	M		
Canvasback	M			Franklin's Gull	M		
Greater Scaup	M			Bonaparte's Gull	M		
Lesser Scaup	M			Forster's Tern	M		
Common Goldeneye	M			Common Tern	M		
Bufflehead	M			Caspian Tern	M		
Ruddy Duck	M			Black Tern		B	
Hooded Merganser	M			Rock Dove		B	
Common Merganser	M			Mourning Dove		B	
Red-Breasted Merganser	M			Yellow-Billed Cuckoo		B	
Turkey Vulture	M			Black-Billed Cuckoo		B	
Goshawk	M			Barn Owl			R
Sharp-Shinned Hawk	M			Screech Owl		B	
Cooper's Hawk		B		Great-Horned Owl		B	
Red-Tailed Hawk		B		Snowy Owl	M		
Red-Shouldered Hawk		B		Barred Owl		B	
Broad-Winged Hawk	M			Long-Eared Owl		B?	
Rough-Legged Hawk	M			Short-Eared Owl	M		
Bald Eagle	M			Saw-Whet Owl			R
Marsh Hawk		B		Whip-Poor-Will		B	
Osprey	M			Nighthawk		B	
Merlin	M			Chimney Swift		B	
Kestrel, American		B		Ruby-Throated Hummingbird		B	
Ruffed Grouse			R	Belted Kingfisher		B	
Bobwhite			R	Flicker		B	
Ring-Necked Pheasant (Introduced)		B		Pileated Woodpecker		B	
Gray Partridge (Introduced)		B		Red-Bellied Woodpecker		B	
Sandhill Crane	M			Red-Headed Woodpecker		B	
King Rail			R	Yellow-Bellied Sapsucker		B	
Virginia Rail		B		Hairy Woodpecker		B	
Sora Rail		B		Downy Woodpecker		B	
Common Gallinule		B		Eastern Kingbird		B	
American Coot		B		Great Crested Flycatcher		B	
Semipalmated Plover	M			Phoebe, Eastern		B	
Killdeer		B		Yellow-Bellied Flycatcher			R
American Golden Plover	M			Acadian Flycatcher		B	

Table 87 (continued)

Birds	Migrant	Breeder	Rare
Traill's Flycatcher (Alder)		B	
Least Flycatcher		B	
Wood Pewee		B	
Olive-Sided Flycatcher	M		
Horned Lark		B	
Tree Swallow		B	
Bank Swallow		B	
Rough-Winged Swallow		B	
Barn Swallow		B	
Cliff Swallow			R
Purple Martin		B	
Blue Jay		B	
Crow		B	
Black-Capped Chickadee		B	
Tufted Titmouse		B	
White-Breasted Nuthatch		B	
Red-Breasted Nuthatch	M		
Brown Creeper		B	
House Wren		B	
Winter Wren	M		
Bewick's Wren	M		
Long-Billed Marsh Wren		B	
Short-Billed Marsh Wren		B	
Gray Catbird		B	
Brown Thrasher		B	
American Robin		B	
Wood Thrush		B	
Hermit Thrush	M		
Swainson's Thrush	M		
Gray-Cheeked Thrush	M		
Veery		B	
Eastern Bluebird		B	
Blue-Gray Gnatcatcher			R
Golden-Crowned Kinglet	M		
Water Pipit	M		
Bohemian Waxwing	M		
Cedar Waxwing		B	
Northern Shrike	M		
Loggerhead Shrike			R
Starling (Introduced)		B	
Yellow-Throated Vireo		B	
Solitary Vireo	M		
Red-Eyed Vireo		B	
Philadelphia Vireo	M		
Warbling Vireo		B	
Black and White Warbler		B	
Prothonotary Warbler	M?		
Golden-Winged Warbler		B	
Blue-Winged Warbler		B	
Tennessee Warbler	M		
Nashville Warbler		B	
Northern Parula Warbler	M		
Yellow Warbler		B	
Magnolia Warbler	M		
Cape May Warbler	M		
Black-Throated Blue Warbler	M		
Yellow-Rumped Warbler	M		
Black-Throated Green Warbler	M		
Cerulean Warbler		B	
Blackburnian Warbler	M		
Chestnut-Sided Warbler		B	
Bay-Breasted Warbler	M		
Blackpoll Warbler	M		
Pine Warbler	M		
Palm Warbler	M		
Ovenbird		B	
Northern Water Thrush		B	
Connecticut Warbler	M		
Mourning Warbler		B	
Common Yellowthroat		B	
Wilson's Warbler	M		
Canada Warbler	M		
American Redstart		B	
House Sparrow (Introduced)		B	
Bobolink		B	
Eastern Meadowlark		B	
Western Meadowlark		B	
Yellow-Headed Blackbird		B	
Redwing Blackbird		B	
Orchard Oriole		B	
Northern Oriole		B	
Rusty Blackbird	M		
Brewer's Blackbird	M		
Common Grackle		B	
Brown-Headed Cowbird		B	
Scarlet Tanager		B	
Cardinal		B	
Rose-Breasted Grosbeak		B	
Indigo Bunting		B	
Dickcissel		B	
Evening Grosbeak	M		
Purple Finch	M		
Pine Grosbeak	M		
Common Redpoll	M		
Pine Siskin	M		
American Goldfinch		B	
Red Crossbill	M		
White-Winged Crossbill	M		
Rufous-sided Towhee		B	
Savannah Sparrow		B	
Henslow's Sparrow		B	
Vesper Sparrow		B	
Lark Sparrow		B	
Dark-Eyed Junco	M		
Tree Sparrow	M		
Chipping Sparrow	M		
Harris' Sparrow	M		
White-Crowned Sparrow	M		
White-Throated Sparrow	M		
Fox Sparrow	M		
Lincoln's Sparrow	M		
Swamp Sparrow		B	
Song Sparrow		B	
Lapland Longspur	M		
Snow Bunting	M		

Source: Wisconsin Department of Natural Resources.

Not all birds are viewed as an asset from an ecological, economic, or social point of view. With the advent of urbanization, and therefore the loss of natural habitat, conditions have become less compatible for the more desirable bird species. English sparrows, starlings, grackles, and pigeons have replaced these more desirable birds in certain areas of the watershed because of their tolerance for urban conditions. The red-winged blackbird, which in some agricultural situations is considered to be a pest, is beginning to feel the urban impact as wetland areas, particularly cattail marshes, are drained or filled.

Mammals: A variety of mammals ranging in size from large animals like the northern white-tailed deer to small animals like the pygmy shrew is found in the Menomonee River watershed. Table 88 lists 47 mammals whose ranges extend into the watershed.

Mammals, common to fairly common in the less densely populated parts of the watershed, include white-tailed deer, cottontail rabbit, gray squirrel, fox squirrel, muskrat, mink, weasel, raccoon, red fox, skunk, and oppossom. The first five are often considered game mammals while the balance are classified as fur-bearing mammals.

White-tailed deer are generally restricted to the larger wooded areas in the northern portions of the watershed. The larger wooded and shrub swamps are also utilized by the deer. While human population and its associated activities create a stressed condition for the deer population, it is estimated that there may be up to 100 deer at times within the watershed. Because of the urban and urbanizing nature of the Menomonee River watershed, there is little potential for an increase in the size of the watershed's deer herd. Human and deer populations living in close proximity are incompatible. When deer wander into or are forced into residential, commercial, or industrial areas, they typically exhibit extreme panic, run wildly, and constitute a threat to people, property, and themselves. Foraging deer sometimes cause damage to gardens, croplands, and orchards. Deer and automobile collisions often occur on the fringes of urban areas and are another example of the stressed conditions that exist when deer inhabit urban-fringe areas.

Table 88

MAMMALS IN THE MENOMONEE RIVER WATERSHED

Opossum	Fox Squirrel
Cinerous Shrew	Red Squirrel
Smoky Shrew	Flying Squirrel
Saddle-Backed Shrew	Prairie Mouse
Water Shrew	Northern White-Footed Mouse
Pygmy Shrew	Cooper's Lemming Mouse
Mole Shrew (Short-Tailed)	Meadow Jumping Mouse
Little Shrew (Short-Tailed)	Red-Backed Vole
Common Mole	Meadow Vole (Field Mouse)
Star-Nosed Mole	Prairie Vole
Little Brown Bat	Pine Vole
Long-Eared Bat	Common Muskrat
Silver-Haired Bat	Norway Rat (Introduced)
Big Brown Bat	House Mouse (Introduced)
Red Bat	Red Fox
Hoary Bat	Gray Fox
Mearns' Cottontail	Raccoon
Woodchuck	Short-Tailed Weasel
Striped Ground Squirrel (13-lined)	Least Weasel
	Long-Tailed Weasel
Franklin's Ground Squirrel	Mink
Gray Chipmunk	Badger
Ohio Chipmunk	Northern Plains Skunk
Gray Squirrel	Northern White-Tailed Deer

Source: Wisconsin Department of Natural Resources.

The cottontail rabbit is abundant throughout the watershed even in urbanized areas. Rabbit hunting is possible in some areas, while many people enjoy observing the activities of this mammal. There is also an abundance of gray squirrels and many fox squirrels in the watershed. The gray squirrel is found primarily in woodlots and wooded residential sections, while the fox squirrel is found in some of the more open woods and countryside. Both require trees of some maturity because the natural cavities in such trees are used for both the rearing of young and for winter protection.

Although there are no detailed data on the actual number of fur-bearing mammals in the watershed, muskrats and mink populations are believed to be relatively low due to the small extent of remaining wetlands. The muskrat is the most abundant and widely distributed fur-bearing mammal in the watershed and may bring a small economic return to some trappers. Muskrats may be attracted to any significant water area in the watershed including wetlands, small ponds, creeks, and drainage ditches all of which may provide suitable habitat. The familiar muskrat house contributes a certain amount of interest to the landscape and is often used by other wildlife. Waterfowl may make use of the houses for nesting, and mink and raccoon occasionally use muskrat houses as denning areas. Preservation and improvement of muskrat habitat would, therefore, benefit waterfowl, mink, and the raccoon. In areas near the Menomonee River watershed, trapping still provides an income supplement to part-time trappers in that a 40-acre marsh can provide a sustained yield of over 100 muskrats a year. When residential development occurs contiguous to muskrat habitat, infrequent but dangerous situations can occur if a muskrat gets cornered by dogs or children.

The raccoon usually is associated with the woodland areas of the watershed; however, much of the raccoon's food is water-based, so it makes considerable transient use of wetland areas. Scavenging raccoons can become pests in wooded environments that contain weekend cottages, campgrounds, and other recreational areas occasionally used by humans.

The red fox is more characteristic of mixed habitat and farmland. Most people are tolerant of the fox due to its aesthetic appeal, while others, less well informed, consider it a threat to other wildlife.

Skunks and oppossums are common watershed furbearers and are becoming of increasing interest as pelt values go up. Both of these mammals inhabit woodland areas bordering farmlands and venture into wetlands in search of food. Skunks and oppossums tend to become inactive in cold weather, although neither is a true hibernator.

Bats, despite their appearance and nocturnal habits, generally have a positive impact on the urban environment in that they are major insect predators, often consuming one-third their weight in insects a night. With the removal of their woodland and wetland habitats by urban development, the more adaptable species of these flying mammals may relocate within that urban development.

Some of the mammals likely to be found in the Menomonee River watershed may serve as vectors for diseases such as rabies. Skunks, raccoons, rodents, and some bats have been noted as being rabid at certain times of the year. Residents of newly urbanizing areas on the fringes of existing development have a greater chance of coming into contact with disease-carrying mammals.

Overview: As a result of urban and agricultural activity and the associated decrease in woodlands, wetlands, and other natural areas, wildlife habitat in the Menomonee River watershed has been seriously depleted. The habitat that remains—except for much of the Milwaukee County Park System—generally consists of land parcels that have not been considered suitable for cultivation or urban development. Much of the remaining habitat has been modified or has deteriorated and some of these remaining habitat areas are being increasingly stressed by approaching or encircling urban development.

As a consequence of the decrease in wildlife habitat, the wildlife population within the watershed has decreased. The fish, amphibian, reptile, bird, and animal species once abundant to the watershed have diminished in type and quantity wherever intensive urbanization has occurred. Certain wildlife species, such as some songbirds, have the capacity to exist in small islands of undeveloped land within the urban complex or to adapt to the urban landscape, but this characteristic is not generally shared by most wildlife.

The most important consideration in maintaining and increasing the existing remnants of wildlife in the watershed lies in achieving the required amount, type, and pattern of habitat and, therefore, in providing a land use pattern within the watershed that preserves the remaining good habitat. It is also necessary to constantly remember that all wildlife species are dependent in one way or another on each other. This means that the loss of habitat for one species has an adverse effect on certain other species, even though the required habitat for these other species remains.

Potential Values

Although little remains of the natural wildlife habitat that once existed within the watershed and, consequently, little remains of the wildlife that once inhabited those areas, that which does remain has the potential to significantly contribute to the quality of life in the watershed if selected portions are protected and properly managed. Wildlife have aesthetic, ecological, educational and research, and recreational value.

Aesthetic Value: Wildlife habitat areas, with their usual variety and richness of vegetal types, have an inherent scenic value in the watershed. These scenic values are heightened if the wildlife habitats are in relatively close proximity to urban development and can, therefore, provide a welcome and restful visual contrast to the urban scene. The aesthetic impact of wildlife habitat is enhanced by observation of the various forms of wildlife—fish, amphibians, reptiles, mammals, and birds—that inhabit those areas. Some forms of wildlife—such as the birds—are readily seen and heard by even the most casual observer whereas the viewing of other forms requires closer examination.

Through thoughtful planning and management, some of the aesthetic benefits of wildlife and their habitat can become an integral part of the urban scene as illustrated by the Milwaukee County Park System. This system of moderate quality linear and continuous wildlife habitat areas is readily accessible to the urban population in the Milwaukee County portion of the Menomonee River watershed. Opportunities for similar aesthetic experiences could be provided in the Ozaukee, Washington, and Waukesha County portions of the watershed. These portions of the watershed contain a variety of moderate, good, and high quality wildlife habitat areas, most of which are in private ownership, but could be acquired to form interconnected linear wildlife habitat.

Ecological Function: All wildlife species within the ecosystem of the watershed and its environs are interdependent. This means that the loss of one species, through destruction of its particular ecological niche, has an adverse effect on certain other wildlife species even though the ecological niche for those species remains intact.

From a narrow human perspective, a quality environment might be one rich in certain "desirable" wildlife species, such as songbirds, and devoid of "troublesome" members of the animal community such as insect pests. However, it is not possible to have the benefit of the most "desirable" elements of the wildlife community without accepting the whole of it.

The ecological importance of the watershed's woodlands and wetlands and the wildlife residing in such habitats was discussed earlier in this chapter and will not be discussed in detail here. These attributes include protection of the biologically most productive areas, the importance of maintaining diversity in watershed biota because of their ecological control function, and the value of preserving open space linkages between wildlife habitat areas. If adequately protected and properly managed, the remaining wildlife habitat in the watershed has the potential to provide the minimum elements needed to maintain the watershed's ecologic system.

Education and Research Function: Wildlife in the context of their habitat are valued by educators, naturalists, and researchers as objects of observation and study. The potential education and research function of wildlife and their habits is very similar to the education and research value of woodland-wetland areas which are discussed earlier in this chapter. The remaining wildlife and wildlife habitat of the Menomonee River watershed have the potential to meet the educational needs of watershed residents provided that selected sites throughout the basin are protected by public or private acquisition for that purpose.

Recreation-Related Values: The presence of wildlife contributes to the enjoyment of certain outdoor recreational activities. There is, for example, opportunity for development of a recreational fishery in some of the watershed's stream system provided that the adopted water use objectives and supporting standards are achieved. Bird watching and photographing may be readily enjoyed by residents of the urban and urbanizing Menomonee River watershed provided that sufficient habitat is preserved. Opportunities for hunting are limited in the watershed because of the small size of the remaining habitat areas and, equally important, because of their close proximity to urban areas. Hunting for rabbit and other small game is presently possible in the headwater portion of the basin but even these hunting opportunities will diminish with the advance of urban development.

ECOLOGIC UNITS

The Menomonee River watershed may be divided into eight ecologic units as shown on Map 81 to provide a basis for better understanding the natural resource base of the watershed as it affects environmental quality. These ecologic units were selected so as to be homogeneous with respect to such elements of the natural resource base as surface water quality, the extent and quality of the remaining woodlands, wetlands, wildlife habitat, and wildlife. In addition, the ecologic units also were selected to be generally homogeneous in land use and other aspects of man's influence on the natural resource base.

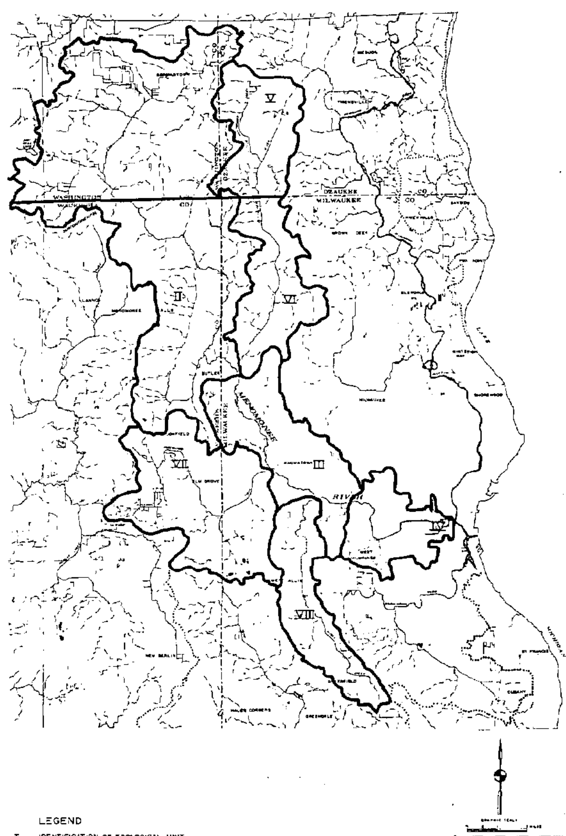
The basic framework within which ecologic units were delineated is the subwatershed. As described in Volume 1, Chapter V, of this report, and shown on Map 45, the Menomonee River watershed contains 14 subwatersheds ranging in size from the Little Menomonee Creek subwatershed which encompasses 3.31 square miles, or 2.4 percent of the total watershed area, to the Upper Menomonee River subwatershed, which covers 29.1 square miles, or 21.5 percent of the total watershed area. The eight ecologic units are either coincident with subwatersheds or are composed of fractions or multiples of the subwatersheds. For example, Ecologic Unit VII, is coincident with the Underwood Creek, South Branch of Underwood Creek, and Dousman Ditch subwatersheds. Ecologic Unit IV consists of the lower portion of the Lower Menomonee River subwatershed, and Ecologic Unit V consists of all of the Little Menomonee Creek subwatershed and the Ozaukee and Washington County portions of the Little Menomonee Creek subwatershed.

The eight ecologic units are also shown on Map 22, Map 23, and Map 24 which summarize, respectively, the woodland-wetland, fishery, and wildlife habitat resources of the watershed. Table 89 presents 1973 fish shocking data on an ecologic unit basis, and Table 90 presents the number and areal extent of unprotected woodland-wetland areas in the watershed by ecologic units. Similarly, Table 91 sets forth the number and size of wildlife habitat areas in the watershed by ecologic units. A summary of relative natural resource values by ecologic unit is presented in Table 92.

Before discussing the individual ecologic units comprising the Menomonee River watershed, it is necessary to establish an overall perspective for all the ecologic units. If the Menomonee River watershed were relatively undisturbed, the lower portions of the basin would exhibit the greatest natural biological productivity, because woodland, wet-

Map 81

ECOLOGIC UNITS IN THE MENOMONEE RIVER WATERSHED



The Menomonee River watershed was partitioned into eight ecologic units to provide a basis for an integrated discussion of the watershed's remaining natural resource base as it affects overall environmental quality. Each of these ecologic units were delineated so as to be approximately homogeneous with respect to the natural resource base and those land uses and activities that man has superimposed on that natural resource base.

Source: SEWRPC.

Table 89

RESULTS OF INSTREAM FISH SHOCKING IN THE MENOMONEE RIVER WATERSHED BY ECOLOGIC UNIT: AUGUST AND SEPTEMBER 1973

Ecologic Unit	Number of Stations	Population and Number of Species According to Relative Tolerance to Organic Pollution												Total								Ratios of Very Tolerant, Tolerant, and Intolerant Populations
		Very Tolerant				Tolerant				Intolerant				All Fish				Sport Fish[a]				
		All Fish		Sport Fish[a]		All Fish		Sport Fish[a]		All Fish		Sport Fish[a]										
		Species	Population	Species	Population	Species	Population	Species	Population	Species	Population	Species	Population	Species	Species Per Station	Population	Population Per Station	Species	Species Per Station	Population	Population Per Station	
I	5	4	1,991	1	356	7	547	3	189	7	254	0	0	18	4	2,792	558	4	1	545	109	7.84/2.15/1.00
II	4	5	356	0	0	6	161	2	22	3	147	0	0	14	4	664	166	2	1	22	6	2.42/1.10/1.00
III	4	4	22	0	0	3	30	1	7	1	8	0	0	8	2	60	15	1	1	7	2	2.75/3.75/1.00
IV	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
V	4	4	22	1	3	4	118	1	10	2	7	0	0	10	3	147	37	2	1	13	3	3.14/16.86/1.00
VI	2	2	3	0	0	2	13	0	0	0	0	0	0	4	2	16	8	0	0	0	0	-
VII	2	3	24	0	0	6	162	4	53	2	24	0	0	11	6	210	105	4	2	53	27	1.00/6.75/1.00
VIII	2	1	3	0	0	1	7	1	7	0	0	0	0	2	1	10	5	1	1	7	4	-
Total	24	6	2,421	1	359	9	1,038	4	288	8	440	0	0	23	-	3,899	-	5	-	647	-	5.50/2.36/1.00

[a] *Sport fish are defined as the following species: black bullhead (Ictalurus melas), green sunfish (Lepomis cyanellus), pumpkinseed (Lepomis gibbosus), bluegill (Leopmis macrochirus), and largemouth bass (Micropterus salmoides). The yellow perch (Perca flavescens) has been omitted from this list as it was collected only at the pond stations.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

land, and surface water resources are normally concentrated—in terms of areal extent and diversity—in the lower portion of a watershed. As a result of urbanization, however, these areas of the greatest historical biological productivity have been largely destroyed.

Paradoxically, it was the natural values of the lower portions of the Menomonee, Milwaukee, and Kinnickinnic River watersheds that attracted the early settlers who initiated the urbanization process. Here these settlers found the fish, game, and furbearers required to supply living essentials and the surface waters on which to transport them. Accordingly, the natural values of these watershed resources led to their destruction, a pattern of exploitation that prevails in watersheds throughout the world and emphasizes the importance of selectively preserving and enhancing dwindling natural resources that still exist in headwater areas and in other sites remote from the mouths of rivers.

A comparative discussion of the natural resources in the ecologic units requires a common focus to serve as an index of relative environmental quality. For purposes of the following discussion, animal life as indicated by the area of wildlife habitat and the relative number of fish taken in the fish shocking survey was selected as the principal index of environmental quality. Therefore, the eight ecologic units in Table 92 are listed in order of decreasing abundance of wildlife, and are also discussed below in terms of decreasing abundance of wildlife. Table 92 clearly indicates that the natural resource values in each of the ecologic units are directly related to the degree of urbanization in that the quantity, quality, and diversity of wildlife habitat, fish life, and woodlands-wetlands decline across the watershed in a generally northwest to southeast direction, that is, in the direction of older and more dense urban development.

The size and diversity of species populations are dependent on the existence of continuous, diverse habitats. Natural disturbances such as fires, floods, weather extremes, and predation result in temporary changes in the flora and fauna of the ecosystem. Populations of living organisms fluctuate around a stable mean in that wildlife species can tolerate both natural short- and gradual long-term natural changes without irreversible damage. However, drastic man-induced changes such as drainage and land clearing for development destroy the wild flora and fauna of the ecosystem. While the riverine corridors have been altered too much to contribute undisturbed habitat, enough acreage has been preserved in parkways in the Milwaukee County portion of the basin to sustain many species of wildlife. These parkways constitute continuous wildlife corridors that physically link rural and suburban portions of the watershed with the public parks in the metropolitan area.

Ecologic Unit I-Northwest

This unit encompasses the North Branch of the Menomonee River subwatershed, the West Branch of the Menomonee River subwatershed, most of the Willow Creek subwatershed, and the Washington County portions of the Upper Menomonee River and Nor-X-Way Channel subwatersheds. Unit I contains the most and best remaining wildlife habitat and the largest fish population. Four wetlands—the Germantown Swamp, the USH 41-45 Swamp, the Hoelz Swamp Forest, and the Willow Creek Headwaters Forest contribute significantly to the wildlife habitat of Ecologic Unit I although only the Germantown Swamp has a high quality ranking as a wildlife habitat. About 72 percent of the fish captured in the fish shocking survey were taken within this ecologic unit. Out of the 100 wildlife habitat sites in the watershed, 45 are in Ecologic Unit I. These remaining sites and several scattered small natural areas make the wildlife habitat in Unit I as good as in any other watershed in southeastern Wisconsin.

Ecologic Unit II-West Central

This ecologic unit contains the Lilly Creek subwatershed, the Butler Ditch subwatershed, small portions of the Willow Creek and Nor-X-Way Channel subwatersheds and the lower portion of the Upper Menomonee River subwatershed. Unit II contains about half as much wildlife habitat as does Unit I. The principal natural feature of Ecologic Unit II is the 334 acre portion of the Tamarack

Table 90

UNPROTECTED WOODLAND-WETLAND AREAS IN THE MENOMONEE RIVER WATERSHED BY ECOLOGIC UNIT: 1973

Ecologic Unit	Value Rating								Total			
	High		Good		Moderate—of Parkway Significance		Moderate—of Local Significance					
	Number of Sites	Acres	Number of Sites	Acres	Number of Sites	Acres	Number of Sites	Acres	Number of Sites	Percent of All Sites in Watershed	Area in Acres	Percent of Total Woodland-Wetland Areas in Watershed
I[a]	0	0	3	626	5	704	2	93	10	45.5	1,423	51.5
II	0	0	3	382	2	155	0	0	5	22.7	537	19.4
III	0	0	0	0	1	16	0	0	1	4.6	16	0.6
IV	0	0	0	0	0	0	0	0	0	0.0	0	0.0
V	0	0	0	0	2	269	1	55	3	13.6	324	11.7
VI	0	0	0	0	0	0	0	0	0	0.0	0	0.0
VII	1	89	0	0	0	0	2	376	3	13.6	465	16.8
VIII	0	0	0	0	0	0	0	0	0	0.0	0	0.0
Total	1	89	6	1,008	10	1,144	5	524	22	100.0	2,765	100.0

[a] *Although a small portion of Woodland-Wetland Site 9 lies in Ecologic Unit II, the entire site was assigned to Ecologic Unit I for purposes of this table.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 91

WILDLIFE HABITAT AREAS IN THE MENOMONEE RIVER WATERSHED BY ECOLOGIC UNIT: 1973

Ecologic Unit	Value Rating								Total			
	High		Good		Moderate		Low					
	Number of Sites	Nominal Acreage[a]	Number of Sites	Nominal Acreage[a]	Number of Sites	Nominal Acreage[a]	Number of Sites	Nominal Acreage[a]	Number of Sites	Percent of All Sites in Watershed	Nominal Acreage[a]	Percent of Total Habitat Areas in Watershed
I	1	560	12	1,440	27	2,320	5	400	45	45	4,720	42.1
II	2	480	0	0	14	1,760	6	480	22	22	2,720	24.3
III	0	0	1	80	3	400	0	0	4	4	480	4.3
IV	0	0	0	0	0	0	0	0	0	0	0	0.0
V	0	0	5	400	5	720	0	0	10	10	1,120	10.0
VI	0	0	1	240	7	560	0	0	8	8	800	7.1
VII	0	0	3	720	6	480	1	80	10	10	1,280	11.5
VIII	0	0	0	0	1	80	0	0	1	1	80	0.7
Total	3	1,040	22	2,880	63	6,320	12	960	100	100	11,200	100.0

[a] *The precise areal extent of a given wildlife habitat is indeterminable and therefore the size of each habitat is specified by one of the following acreage ranges: 0-160, 161-320, 321-480, 481,640, and 640-800. For purposes of acreage totals in this table, the size of each wildlife habitat area was taken as the midpoint in its size range. For example, a habitat area in the 161-320 acreage range was assigned a nominal area of 240 acres.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 92

RELATIVE NATURAL RESOURCE VALUES IN THE MENOMONEE RIVER WATERSHED BY ECOLOGIC UNIT: 1974

Ecologic Unit		Wildlife Habitat in Acres	Unprotected Woodland-Wetlands in Acres[a]	Fish Captured per Station in 1973 Fish Shocking Survey
Number	Name			
I	Northwest	4,720	1,423	558
II	West Central	2,720	537	166
VII	Southwest	1,280	465	105
V	Northeast	1,120	324	37
VI	Northeast Central	800	0	8
III	Southeast Central	480	16	15
VIII	South	80	0	5
IV	Southeast	0	0	--[b]
Total		11,200	2,765	--

[a] *Woodland-wetland areas are generally also portions of larger wildlife habitat and therefore most of the woodland-wetland acreage is included in the wildlife habitat acreage.*

[b] *No stations sampled along the main stem in Ecologic Unit IV.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Swamp that lies within the watershed. Although a considerable amount of wildlife habitat still exists in this ecologic unit, most of it—over 80 percent—is in the moderate and low quality categories. Ecologic Unit II ranks second to Unit I in the number of fish taken per station during the fish shocking survey.

Ecologic Unit VII-Southwest

This unit is coincident with the Underwood Creek, South Branch of Underwood Creek, and Dousman Ditch subwatersheds. About half as much wildlife habitat as in Unit II remains in this ecologic unit. At the time of the 1973 field inventory of natural resources in the watershed, Unit VII contained the only high quality woodland-wetland in the watershed in the form of Bishops Woods—a 90 acre upland hardwood forest. Attempts to acquire it as a State Scientific Area have failed and the woods have now been significantly disturbed, reduced in size, and diminished in value as a result of an office park development. The three-segment Brookfield Swamp, a good quality wildlife habitat, is also located in Ecologic Unit VII. This ecologic unit ranked third in the number of fish captured per station during the fish shocking survey, as well as third in the number of different species identified.

Ecologic Unit V-Northeast

This ecologic unit, which is located along the upper reaches of the Little Menomonee River, contains slightly less wildlife habitat than Unit VII with the overall quality being noticeably less than that of Unit VII. The small amount of good quality wildlife habitat in Unit V is all contained within the Little Menomonee Creek subwatershed. Most of the habitat within Unit V is closely aligned with the riverine areas and therefore has potential for inclusion in public parkway and open space areas. This ecologic unit ranked fourth in the number of fish captured per station during the fish shocking survey.

Ecologic Unit VI-Northeast Central

This unit, which encompasses the area tributary to the lower half of the Little Menomonee River, contains about three-fourths as much wildlife habitat as Unit V and is essentially devoid of fish. As was the case with Unit V, most of the remaining wildlife habitat in Unit VI is closely aligned with the riverine areas. However, whereas almost all the riverine area wildlife habitat in Unit V is in private ownership, essentially all the riverine area wildlife in Unit VI is part of the Milwaukee County Park System. Although most of the Unit VI wildlife habitat areas are only of moderate value, they provide, by virtue of the contrast they furnish, a substantial contribution to the quality of life in the adjacent urban areas.

Ecologic Unit III-Southeast Central

This ecologic unit contains lands directly tributary to the Lower Menomonee River reach in the City of Wauwatosa. The small amount of wildlife habitat area that remains in this unit is within the Milwaukee County Park System lands along the Menomonee River and essentially all of it is of only moderate quality. In terms of population per station, the number of fish captured in Ecologic Unit III ranked fifth among the eight ecologic units. In spite of their relatively low rating as a wildlife habitat, the continuous, riverine area woodlands and open spaces in this unit enhance the quality of life for the urban population in the adjacent residential areas.

Ecologic Unit VIII-South

Coincident with the Honey Creek subwatershed, this ecologic unit contains a token amount of wildlife habitat—less than 80 acres—concentrated in Milwaukee County Park System lands at the downstream end of the unit. This unit is essentially devoid of a fish population. In contrast with the six previously discussed ecologic units, each of which contained significant amounts of natural areas, Unit VIII and the last unit, Unit IV, provide examples of urban environments in which essentially no natural values remain.

Ecologic Unit IV-Southeast

This unit contains that intensively developed portion of the watershed tributary to the Menomonee River industrial valley. No wildlife habitat areas were identified in this unit and, although no fish shocking surveys were conducted here, the water quality is such that the existence of a desirable fishery is unlikely.

DEMAND FOR OUTDOOR RECREATIONAL LANDS

The prceding portions of this chapter have discussed the existing status and potential value of the watershed's streams, woodland and wetland areas, and wildlife habitats with emphasis on the variety and wide spectrum of environmental values associated with such areas, namely aesthetic amenities, ecological functions, education and research utilization, and recreation-related uses. This portion of the chapter is devoted to additional analysis of the last of the above values—recreation—and is concerned with determining the existing and forecast gross recreational land needs and the relationship between those land needs, the existing outdoor recreation lands, and the potential outdoor recreation lands.

Data and information on existing and potential outdoor recreation and related open space sites were presented in Chapter III of this volume and have been incorporated into the analyses presented in the remainder of this chapter. As indicated in Chapter III, a recent inventory conducted by the Regional Planning Commission indicated the existence of 243 public and nonpublic park, outdoor recreation, and related open space sites in the watershed totaling 6,138 acres, or about 7 percent of the watershed area. Of the 18 potential park recreation and related open space sites in the watershed, 14 are small, being 150 acres or less in size, and only three were classified as high value sites.

The quality of life for the residents of an area is dependent, in part, on accessibility to a wide range of recreational opportunities. The importance of recreational experiences is heightened in urban and urbanizing areas like the Menomonee River watershed because such experiences provide a welcome and needed contrast to the more intense style of urban living. Furthermore, the very same urbanization process that heightens the value of recreational experiences for the urban dweller has the potential to eliminate or markedly deteriorate the remaining potential recreation sites. If the recreation potential of the Menomonee River watershed is to be protected and developed to meet the growing demand for outdoor recreational opportunities, appropriate attention must be given in the comprehensive watershed planning effort to both a quantification of the existing and potential demand for outdoor recreation and to the means available to satisfy this demand through public and private investment in outdoor recreational facility development.

Factors Affecting the Existing and Future Demand for Outdoor Recreational Lands

Seasonal Variation: The greatest use of outdoor recreational lands within the Menomonee River watershed may be anticipated in the summer vacation season, extending from Memorial Day weekend in May through the Labor Day weekend in September. This approximately three-month-long-period of intensive use coincides with the warmest season of the year, the longest daylight hours, and the annual vacation times for the majority of persons having children affected by school-term residence requirements. Within this summer period of high outdoor recreational activity, the most intense uses generally occur on weekend days and on holidays.

Urbanization Within the Watershed: Urbanization within the watershed is already exerting a direct and rapidly increasing pressure on its recreational resources. This urbanization, as evidenced by both population increase and land use changes, has been particularly striking during recent decades. For example, in the 20-year period from 1950 to 1970, a 42 percent increase in watershed population was accompanied by an approximately 156 percent increase in land devoted to urban use within the watershed. This marked urban expansion has increased the demand for recreational areas while simultaneously resulting in a significant reduction in the amount of undeveloped land suitable to satisfy the recreational demands. Although the watershed population is expected to increase by about 40,000 persons, or by 11.5 percent, by the year 2000, additional recreational pressures may be expected to occur as a result of the increased leisure time and environmental awareness of area residents with an attendant increase in per capita demands for nearby outdoor opportunities. This will be further complicated by the expected redistribution of the watershed population thereby increasing the number of residents in the upper portion of the watershed and therefore the recreational demands placed on that area.

Urbanization Outside of the Watershed: Not only is the Menomonee River watershed located within the Southeastern Wisconsin Region, one of the large urban regions of the United States, but it is located also in close proximity to the northeastern Illinois metropolitan region, the third largest urban region in the United States. Both of these regions are experiencing rapid population growth and urbanization. By the year 2000, for example, about 1.73 million people are expected to reside within Milwaukee, Ozaukee, Washington, and Waukesha Counties the four counties comprising the watershed, producing an increase of 24 percent over the 1970 four-county population of 1.40 million.[13]

[13] *The 1970 populations of Milwaukee, Ozaukee, Washington, and Waukesha Counties were 1,054,249; 54,461; 63,839; and 231,335 people, respectively, for a total of 1,403,884. The forecast year 2000 populations of Milwaukee, Ozaukee, Washington, and Waukesha Counties are 1,059,000; 114,000; 143,000; and 420,600 people, respectively, for a total of 1,736,600.*

While an increased demand for outdoor recreation is certain to be generated by the increase in regional population and by increasing affluence, it is unlikely that a significant portion of the outdoor recreation pressure exerted on the Southeastern Wisconsin Region will be imposed on the watershed by out-of-state visitors. The inventory of existing and potential recreation and related open space lands within the watershed indicates that the quality and size of these areas is such that they are unlikely to attract users from outside of the watershed. Thus, most of the pressure exerted on the recreational resources of the Menomonee River watershed will be applied by residents of the watershed and immediately adjacent areas during short—less than one day—recreational outings.

Outdoor Recreational Activity Demand

Relationship between the Menomonee River Watershed Planning Program and the Regional Park, Outdoor Recreation and Related Open Space Planning Program: In June 1973, the Commission undertook the preparation of a regional park, outdoor recreation and related open space plan. Existing and potential recreation and related open space data and information obtained during the first year of that planning program have been fully integrated into the Menomonee River watershed planning program. However, because the watershed planning program was scheduled for completion in 1975, before the regional park planning program, it was necessary to proceed with the analysis of existing and forecast outdoor recreation activity for the Menomonee River watershed without the benefit of the similar analysis to be conducted on a regional basis for the park, outdoor recreation and related open space planning program.

A technique, based on Wisconsin Department of Natural Resources survey data, was developed for estimating existing and forecast outdoor recreation activity demand imposed on the watershed. While this procedure provides a good first approximation of existing outdoor recreational activity that is suitable for watershed planning purposes, it is anticipated that the analyses and forecast methods used in the regional park planning program will provide better estimates because they will be based on more recent recreation user surveys conducted specifically for the regional park planning program within the Southeastern Wisconsin Region.

Procedure Used to Estimate Existing Outdoor Recreational Activity by Watershed Residents: Based on statewide data collected in a 1970 telephone survey of 9,330 Wisconsin households, the Wisconsin Department of Natural Resources developed estimates of 1970 recreational activity by residents of each of the 72 counties in the state.[14] These estimates were prepared for the 17 major recreational activities set forth in the first column of Table 93.[15] Five of the 17 outdoor recreational activities are categorized as water-based in that the presence of water sufficient in areal or lineal extent and of adequate quality is necessary for participation in the activity. The other 13 activities are land-based.

Certain common outdoor recreation activities were not explicitly included in the survey and are not, therefore, identified in the list of 17 activities. These activities include, among others, softball, badminton, volleyball, and other similar sports and games often enjoyed as part of the broad activity of picnicking, which was included in the Department of Natural Resources Survey. Although these popular field sports were not explicitly included in the survey and, therefore, in the analysis described below, space for these activities is provided for in the watershed plan through application of park and recreational land standards that support the land use development objectives.

The participation within each of the 17 categories is expressed in terms of participant-days per peak weekend day during the season in which the activity is normally enjoyed, which in most instances is summer. A participant-day for a particular outdoor recreation activity is defined as the participation in that activity by one individual on any day. An individual involved in a recreational outing is very likely to participate in more than one activity on any day. In accordance with the definition of participant-day, each such activity would be counted as one participant-day so that a person is likely to generate or account for more than one participant-day on any given day. Peak weekend days, as opposed to average days, or average weekend days are used by the Department of Natural Resources in reporting the results of the recreation activity survey because the most intense recreational pressure for any recreational activity occurs on a weekend day during the season within which the activity is normally enjoyed.

The Department's estimates of 1970 outdoor recreation activity by Milwaukee County residents were used by the Commission to estimate the 1970 outdoor recreation activity demand imposed on the watershed in accordance with the following procedure:

1. The recreation activity engaged in by the residents of Milwaukee County was assumed to be representative of the recreation preferences of residents of the urban and urbanizing Menomonee River watershed who might seek recreational experiences within the watershed.

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[14] *See:* Wisconsin Outdoor Recreation Plan-1972, *Wisconsin Department of Natural Resources, Bureau of Planning, Publication No. 802-72, 1972. Supporting county data obtained from the Wisconsin Department of Natural Resources is on file in the Commission offices.*

[15] *Although the Department of Natural Resources survey developed participation data for hunting, the data were not used in this analysis since they were expressed in terms of average daily participation rather than in terms of peak weekend day participation. The survey also included off-the-road motor sports but these data indicated no such activity by Milwaukee County residents and therefore this category was omitted from the analysis.*

2. Inasmuch as it is desirable to satisfy most recreational demands as near to the place of residence as possible, it was further assumed that the Milwaukee County demand could be transferred to the watershed on the basis of population. Accordingly, the 1970 outdoor recreational demand was estimated as the product of the Milwaukee County demand and the ratio of the 1970 watershed population of 348,165 persons and the 1970 Milwaukee County population of 1,054,249 persons.

The resulting estimates for the watershed are presented in Table 93 along with rank and relative participation information. The estimating procedure as described is considered to provide an adequate first approximation of the 1970 outdoor recreational activity by residents of the Menomonee River watershed. It should be emphasized that the outdoor recreational activity data set forth in Table 93 represent an estimate of the outdoor recreation demand that should ideally be satisfied within the watershed, that is, near the place of residence of those people exerting the demand.

Characteristics of Existing Outdoor Recreational Activity by Watershed Residents: The total outdoor recreational activity demand on the Menomonee River watershed is estimated to be about 126,000 participant-days per peak seasonal weekend day. As shown in Table 93, the four most popular outdoor recreational activities are swimming, picnicking, fishing, and target shooting—the latter including archery, rifle, pistol, and shotgun—which together account for 56 percent of the demand.

One of the more surprising aspects of the existing and forecast outdoor recreational activity demand for the Menomonee River watershed is the relatively high popularity of target shooting. This activity which includes—in addition to trap shooting—archery, pistol, and rifle target shooting was found to be the fourth most popular outdoor recreational activity based on participant-days per peak seasonal weekend day. This may be surprising to some people, probably because this activity is usually not readily observed by other outdoor recreation participants for two reasons. First, target shooting facilities[16] are, for safety reasons, generally not located in close proximity to other recreational lands or facilities and therefore participants in a wide range of outdoor recreational activities are not likely to observe target shooting. Second, although the various types of target shooting are enjoyed year-round, this activity tends to exhibit a seasonal peak with considerable activity occurring in the early fall prior to the beginning of hunting seasons at a time when activity in many other outdoor recreation activities is significantly reduced, thereby effectively diminishing the "visibility" of the target shooter.

Water-based outdoor recreational activities, as previously indicated, are those activities which require access to a body of water. Demand for water-based activities in the watershed currently accounts for almost 43 percent of the total outdoor recreation demand. As shown in Table 93, three of the six highest ranked activities based on participation demand—swimming, fishing, and motor boating—require surface water. These three activities together account for 40 percent of the outdoor recreation demand in the watershed.

Land-based outdoor recreational activity demand currently comprises about 57 percent of the total demand. Pleasure driving—which accounts for 14 percent of all land-based outdoor recreation activity demand—is an example of a popular activity that does not require public recreation land, but simply requires the availability of a network of scenic drives and rustic roads routed over the existing highway system together with the maintenance of the visual beauty of the countryside and the preservation of sites of scenic and historic interest.

Forecast Outdoor Recreational Activity by Watershed Residents: As noted earlier in this chapter, the total demand for recreational activity demand on the watershed residents may be expected to increase primarily as a result of two additive effects: the increased leisure time and environmental awareness of area residents with an attendant increased per capita demand for recreational activities, and the forecast increase in population. Although the forecast increase in watershed population is moderate, it is likely that the incremental recreation activity demand placed on the watershed may be expected to increase approximately in proportion to the forecast 24 percent increase by the year 2000 in the population of Milwaukee, Ozaukee, Washington, and Waukesha Counties in which the watershed lies. The incremental recreation activity demand attributable to increased individual leisure time and environmental awareness is an intractable forecasting problem in the absence of data based on a survey of residents of the watershed and its urban environs. While such data will become available upon completion of the Commission's regional park planning program, the necessary information was not available during the analysis and forecast phase of the Menomonee River watershed planning program. Consequently, an increase of 25 percent in recreational demand over the 30 year planning period was assumed, based primarily upon the forecast population increase in the counties in which the watershed lies. The resulting forecast demand for 17 outdoor recreation activities is presented in Table 93. As was the case with the existing outdoor recreation demand, the forecast demand is intended as a first approximation, adequate for watershed planning purposes.

Outdoor Recreational Land Needs

For watershed planning purposes, existing and forecast demands for recreational activity must be converted to attendant demand for recreational land. Participant

[16] *Data obtained under the SEWRPC Regional Park, Outdoor Recreation and Related Open Space Planning Program reveals that there are about 70 public and private outdoor archery ranges, pistol, and rifle shooting facilities and trap shooting facilities in the four-county Milwaukee, Ozaukee, Washington, and Waukesha Counties area. These facilities do not include indoor archery, pistol, and small-bore rifle ranges that also exist within the four-county area.*

demand for outdoor recreational activity must therefore be converted to land needs by the application of agreed upon area-use standards. Subtracting the total lands presently owned or developed for recreational activities from the results of this conversion will provide a measure of the deficiencies of the presently available recreational areas and thus a measure of total land needs. In such an analysis, it must be recognized that certain recreational activities require intensively developed recreational sites, while others do not. Consequently, as shown in Table 94, the major outdoor recreational activities previously discussed in this chapter have been grouped into four

Table 93

ESTIMATED EXISTING AND FORECAST OUTDOOR RECREATIONAL ACTIVITY DEMAND IN THE MENOMONEE RIVER WATERSHED

Major Recreational Activity	Existing (Year 1970) Participation (Participant-Days) Per Peak Weekend Day[a]	Forecast (Year 2000) Participation (Participant-Days) Per Peak Weekend Day[b]	Rank	Participation Relative to Swimming
Water-Based				
Swimming	27,450	34,350	1	1.000
Fishing	13,350	16,700	3	0.486
Motor Boating	9,000	11,250	6	0.031
Water Skiing	3,050	3,800	12	0.111
Canoeing	850	1,050	15	0.018
Subtotal	53,700	67,150	--	--
Land Based				
Target Shooting[c]	12,850	16,050	4	0.468
Picnicking	16,550	20,700	2	0.602
Snowmobiling	7,050	8,800	8	0.257
Pleasure Driving[d]	10,200	12,750	5	0.371
Pleasure Walking	7,200	9,000	7	0.262
Camping[e]	5,800	7,250	9	0.211
Snow Skiing	4,100	5,150	10	0.150
Horseback Riding	3,450	4,300	11	0.125
Golfing	2,600	3,250	13	0.094
Nature Study	1,350	1,700	14	0.049
Bicycling[f]	500	650	16	0.018
Hiking[g]	225	300	17	0.008
Subtotal	71,875	89,900	--	--
Total	125,575	157,050	--	--

[a] *Source: 1970 Outdoor recreation participation data for Milwaukee County as obtained by the Wisconsin Department of Natural Resources for preparation of Wisconsin Outdoor Recreation Plan-1972, WDNR, Bureau of Planning, Publication No. 802-72, 1972. Total participation for the County was reduced to the Menomonee River watershed in proportion to the 1970 population of the watershed relative to the 1970 population of the County.*

[b] *Preceding column times 1.25 as described in text.*

[c] *Includes bow and arrow, pistol and rifle target shooting, as well as trap shooting. DNR survey values reduced by 10 percent to account for possible inclusion of indoor target shooting activity.*

[d] *Includes only those automobile trips made specifically for a sight-seeing experience.*

[e] *Excludes primitive camping, that is, sites that are generally inaccessible by automobile and do not contain sanitary facilities or other convenience facilities.*

[f] *Includes only bicycle touring, that is, excludes informal and short bicycle use.*

[g] *Walking trips of four hours or more duration.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

classifications based on the types, or degree, of site development required in order to meet demands of participants in each activity. Only the activities in the first group actually require recreation sites per se. Activities in the other three groups can be, at least partially, accommodated on lands already being used for other purposes.

The five major outdoor recreational activities in the first group—picnicking, swimming, snowskiing, golfing, and camping—require intensive site development. Areas with public recreational landholding devoted, or proposed to be devoted, to these uses can be delineated and, therefore, readily separated from other recreational use areas. The

Table 94

SUGGESTED MINIMUM LAND AREA REQUIREMENTS FOR MAJOR OUTDOOR RECREATION ACTIVITIES IN THE MENOMONEE RIVER WATERSHED

Major Recreation Group	Major Activity	Minimum Land or Water Area Requirement per Participant in Square Feet[a]			Daily Participant Turnover Rate[a,d]	Minimum Total Land or Water Area Requirement per Participant per Day in Square Feet
		Principal Development Area[b]	Backup Land or Secondary Development Area[c]	Total Area		
Group 1 Requires Land Ownership and Intensive Development	Picnicking	870	7,830	8,700	1.6	5,440
	Swimming (natural areas)	115	460	575	3.0	190
	Swimming (pools	27[e]	110[f]	137	3.0[e]	45
	Snow Skiing	4,350	435	4,785	3.0	1,600
	Golfing	43,560	0	43,560	3.0	14,500
	Camping	2,900	55,100	58,000	1.0	58,000
Group 2 Requires Extensive Water Area	Motor Boating Fishing Water Skiing Canoeing	These activities require large areas of water and intensive water management. Required land access for boat launching and incidental parking can be accommodated in conjunction with other waterfront recreation or multiuse development or in small isolated tracts readily accessible by motor vehicle (no specific land area requirement).				
Group 3 Requires No Additional Extensive Land Ownership of Development	Snowmobiling Target Shooting Horseback Riding Off-the-Road Motor Sports Nature Study Hiking	These activities can be accommodated on land acquired and developed for other more intensive major recreational activity or on posted private property not specifically developed for recreational purposes (no specific land area requirement).				
Group 4 Requires No Recreation Land Ownership	Pleasure Driving Pleasure Walking Bicycling	These activities can be accommodated entirely within existing public rights-of-way but may also be accommodated on recreation lands and private lands (no specific land area requirement).				

[a] *Based on recreation standards set forth in Chapter II, Volume 2 of this report, unless otherwise indicated.*

[b] *Area specifically developed for the major activity.*

[c] *Area auxiliary to the major activity which may accommodate one or all of the other 17 major activities, as well as minor development and incidental development, such as parking.*

[d] *The number of times each day one specific area of principal development is used by individual participants in that activity.*

[e] *Wisconsin Outdoor Recreation Plan-1972, Wisconsin Department of Natural Resources, Bureau of Planning, Publication No. 802-72, pp. 17-22, 1972.*

[f] *Assumed to be four times the principal development area.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

four activities in the second group—motor boating, fishing, water skiing, and canoeing—require extensive areas of surface waters, with the only intensive development required being boat or canoe launching sites and associated parking areas which can be included with other intensive water-based facility development. Participant demand for the five activities in the third group—snowmobiling, target shooting, horseback riding, nature study and hiking—generally must be met through the use of existing and future public recreation and open space lands, as well as of lands in nonpublic agricultural or other open space uses. Participation in the three activities in the fourth group—pleasure driving, pleasure walking, and bicycling—can be generally accommodated on existing highway rights-of-way, especially if a network of scenic drives and rustic roads is designated within the total street and highway system.

Specific standards in terms of acres of land area for each activity can only be readily developed for the five major activities in the first group. As shown in Table 94, the land required per participant consists of the area specifically developed for the activity, such as a ski slope, plus the necessary backup land or secondary development, such as a parking area. The total area required per participant in each activity is divided by the daily participant turnover rate for each activity which yields the minimum land requirement per participant-day as shown in the last column of Table 94.

Application of the land area per participant-day requirements of Table 94 to the forecast 2000 outdoor recreation activity demand on the watershed for the five major outdoor recreational activities as shown in Table 93 results in total land demand values shown in Table 95. That table also includes the areal extent of existing watershed land and facilities devoted to each of the five outdoor recreation activities thereby permitting a comparison of land requirements to land supply. It should be emphasized that the land demand and supply values set forth in Table 95 consist not only of the principal developed area required for each of the five recreational activities but the necessary "backup land" as well.

Meeting the Year 2000 Outdoor Recreational Land Needs

Considering the watershed as a whole, there are sufficient swimming and picnicking lands and facilities and golf courses to meet the existing and forecast demand of watershed residents for these two activities through the year 2000. However, inasmuch as most of these swimming facilities, picnicking areas, and golf courses are currently concentrated in the urban areas of the watershed, it may be desirable to develop some additional swimming and picnicking sites and golf courses in the northern portions of the basin to facilitate ease of access to such facilities by the residents of the newly urbanizing areas of the watershed.

The watershed is deficient in meeting the forecast camping demand and the attendant land requirement of about 9,650 acres. Currently no campgrounds exist within the watershed, and little potential exists for developing quality camping areas with the capacity to satisfy the camping demand. A limited amount of camping activity could be accommodated in the rural Ozaukee and Washington County portions of the basin since, as indicated in Chapter III of this volume, that area contains eight potential recreation and related open space sites each having an area of up to 150 acres. If all of these sites encompassed 150 acres, and if all were to be developed for camping, the combined area of 1,200 acres would provide only about 12 percent of the area needed to meet the forecast camping demand. It follows, therefore, that the Menomonee River watershed cannot meet, and that the watershed plan should not be designed to attempt to meet, a significant portion of the potential camping demand. Residents of the watershed and the surrounding urban and urbanizing areas will have to travel to other, more rural parts of the Region and the State to satisfy their camping demands.

The watershed is deficient with respect to snow skiing opportunities in that approximately 157 acres of additional land—in additon to the existing 33 acres—are needed to meet the forecast demand. Inasmuch as the required incremental amount of land is small relative to both the 6,138 acres of existing park, outdoor recreation, and related open space sites, as well as the 18 potential recreational and related open space sites in the watershed, it should be feasible for either private interests or public entities to develop the required additional snow skiing facilities within the watershed by the year 2000.

In summary, and with respect to the five outdoor recreation activities listed in Table 95 for which specific land requirements can be determined, swimming and picnicking lands and facilities and golf courses are adequate to meet the forecast year 2000 demands on the Menomonee River watershed whereas camping and snow skiing lands and facilities are inadequate. While there is sufficient land and necessary natural resources within the watershed to permit additional recreational development to meet the forecast snow skiing demand, there is no potential for the development of high quality campgrounds to meet the camping demand.

Although land and water requirements are not readily assigned to them, it may be assumed that the demands for most of the remaining 12 outdoor recreation activities listed in Table 93 can be satisfied either on backup lands auxiliary to those lands supporting more intense outdoor recreational activities or on public rights-of-way. Many of these activities might also be enjoyed in riverine area park and open space lands that could, as discussed earlier in this chapter, be acquired in the Ozaukee, Washington, and Waukesha County portions of the watershed for aesthetic, ecologic, educational, and recreational purposes.

Exceptions to the above are the two water-based activities of motor boating and water skiing and one land-based activity—target shooting. As indicated earlier in this chapter, the surface water resources of the watershed, from a strictly physical perspective, are not able to support such intense water-based activities. Residents of the Menomonee River watershed and adjacent areas who

Table 95

EXISTING AND REQUIRED LAND FOR OUTDOOR RECREATION ACTIVITIES IN THE MENOMONEE RIVER WATERSHED BY SELECTED ACTIVITY

Major Recreational Activity	Forecast (Year 2000) Total Participation (Participant-Day) Per Peak Weekend Day During the Season	Minimum Land Requirement Per (Participant-Day)[a] (square feet)	Total 2000 Recreational Land Demand (acres)	Total 1970 Existing Recreational Land Supply (acres)	Comparison of Land Supply to Land Required			
					Deficit		Excess	
					Acres	Percent of Required	Acres	Percent of Required
Swimming . . .	34,350	45[b]	35	43[c]	--	--	8	23
Picnicking . . .	20,700	5,440	2,585	2,730[d]	--	--	145	6
Camping	7,250	58,000	9,650	0	9,650	100	--	--
Snow Skiing . . .	5,150	1,600	190	33[e]	157	83	--	--
Golfing	3,250	14,500	1,080	1,065[f]	15	1	--	--
Total	70,700	--	13,540	3,871	--	--	--	--

[a] *Principal development area plus backup land or secondary development area.*

[b] *Based on the swimming pool standard of 45 square feet per participant-day.*

[c] *Based on the principal development areas at the following eight outdoor swimming pools locations: Greenfield Park (1.3 acres), Hoyt Park (1.4 acres), Madison Park (1.1 acres), McCarty Park (1.3 acres), Washington Park (1.6 acres), Franklin Wirth Park (0.9 acre), Elm Grove Village Park (0.6 acre), and Western Racquette Club (0.4 acre). The total principal development area of 8.6 acres was increased by a factor of five to 43 acres to account for backup land.*

[d] *Estimated as one-half of the publicly owned park, outdoor recreation and related open space area in the watershed.*

[e] *Based on principal development areas at the following four locations: Dretzka Park (15 acres), Currie Park (3 acres), Franklin Wirth Park (2 acres), and Hansen Park (2 acres). The total principal development area of 22 acres was increased by 50 percent to 33 acres to account for backup land.*

[f] *Based on the total estimated areas of the following six 18-hole golf courses: Dretzka Park (262 acres), Currie Park (165 acres), Lake Park (177 acres), North Hills Country Club (137 acres), Bluemound Country Club (175 acres), and Greenfield Park (106 acres) and the following three 9-hole golf courses: Hansen Park (19 acres), Starlight (5 acres), and Madison (19 acres).*

Source: Southeastern Wisconsin Regional Planning Commission.

wish to participate in these two activities will have to use the inland lakes of southeastern Wisconsin or, if motor boating, Lake Michigan. Because of its urban and urbanizing character, the watershed is generally unsuitable for target shooting activities, particularly those involving firearms. Demands for this type of outdoor recreation activity will have to be satisfied by facilities provided in the rural areas of southeastern Wisconsin.

Relationship of Existing Park, Outdoor Recreation and Related Open Space Lands to Gross Standards for Recreational Lands

The preceding analysis demonstrates that, with a few exceptions—motor boating, water skiing, and target shooting—the existing recreational lands and facilities within the Menomonee River watershed are adequate or could readily be made adequate to satisfy the forecast year 2000 recreational demand. Whereas the aforementioned analysis of the adequacy of recreational lands is based on Wisconsin Department of Natural Resources demand data for 17 activities, it is also possible to evaluate the overall adequacy of recreational lands by application of the gross park and recreational land standards incorporated in Land Use Development Objective 1 as set forth in Chapter II of Volume 2 of this report. This standard calls for a minimum of five acres of regional park and recreational land and 10 acres of local park and recreational land per 1,000 persons residing within the watershed.

Milwaukee County contains two regional parks located wholly or partly in the watershed; a 230-acre portion of Greenfield Park lies within the basin along with the 326-acre Dretzka Park. This combined total of 556 acres of major public outdoor recreation centers provides about 2.0 acres of regional park and recreation land per 1,000 persons, based upon the forecast resident population of the watershed. There is very little potential for development of any additional regional parks in the watershed because of the extensive amount of urban development and the absence of large, open space areas having unique natural features. It follows, therefore, that the regional park standard cannot be met within the watershed and that watershed residents desirous of visiting and using such areas will have to travel to other parts of the Region.

The forecast year 2000 watershed population of about 388,000 persons would require a minimum of about 3,880 acres of local park and recreational land based on the standard of 10 acres of land per 1,000 persons. The watershed contains about 5,582 acres[17] of public and private park, outdoor recreation and related open space land and, therefore, the existing overall supply of local park and recreational land more than satisfies the gross local park and recreational land standard. Indeed, the existing total acreage of public park and outdoor recreation land comes very close to meeting the total combined regional and local park acreage of 5,820 acres required by an application of a combined standard of 15 acres per 1,000 persons. This conclusion is consistent with the general conclusion drawn from preceding analysis of 17 outdoor recreation activities subject to the qualifications that the demand for a few activities cannot be satisfied within the watershed because basic physical requirements are lacking and that the existing park and recreation lands are concentrated in the Milwaukee County portion of the basin where they are not readily available to the western and northern urbanizing areas of the watershed.

SUMMARY

In an urban environment like the Menomonee River watershed, the extent and quality of the natural resource base elements is an important determinant of the health of the ecosystem in general, and the overall quality of life for the human population in particular. In addition to ecological functions, watershed streams, woodlands, wetlands, and wildlife habitat have aesthetic values, provide educational facilities, and provide a setting for outdoor recreational activities. Relative to most other watersheds located wholly or partly within the seven-county Planning Region, the urban and urbanizing Menomonee River watershed contains, with a few exceptions, only remnants of important natural resource elements such as natural streams, woodlands, wetlands, and wildlife habitat. Although only remnants of these key natural resource elements remain—and perhaps because only remnants remain—they have the potential to substantively contribute to the stability of the ecosystem and the quality of life in the Menomonee River watershed.

Historic and recent information indicate a general deterioration in the quality of the sport fishery in the watershed stream system. A 1973 fish shocking survey conducted at 24 locations throughout the stream system revealed the presence of almost eight times as many fish that are very tolerant or tolerant of pollution as there were pollution-intolerant fish. Of the 23 species of fish captured during the instream fish shocking survey, only five species were considered to be of sport fishing value. The dominance of the very tolerant and tolerant fish and the relatively small number of sport fish species is a manifestation of the low surface water quality conditions that exist throughout the watershed.

Although the existing fishery is of little value, a valuable sport fishery could be naturally maintained in the lower portion of the watershed stream system contingent upon achievement of the adopted water quality objectives and supporting standards. With respect to biological requirements, the self-sustaining fishery could be supplemented with a stocked anadromous sport fishery in which large Lake Michigan fish including coho salmon, chinook salmon, Atlantic salmon, brook trout, brown trout, and rainbow trout would move up the Menomonee River and some of its major tributaries during their spawning seasons. The potential recreational benefits of a Lake Michigan-oriented fishery would have to be weighed against certain problems attendant to large numbers of fishermen gathering at crowded public access points during brief periods of the year.

Use of the streams in the lower reaches of the watershed for wading and swimming has significantly declined to the present level of virtually no activity as a result of the polluted nature of the surface waters. Other factors mitigating against use of the streams for swimming include the extensive channel modification works that have been constructed in recent decades, the general shallowness of the streams during the summer period, and the absence of suitable public access in Ozaukee, Washington, and Waukesha Counties. If the water quality and public access deficiencies are resolved, the Menomonee River watershed stream system would have the potential to support limited wading and swimming activities for children.

Only a limited amount of boating activity currently is enjoyed on the watershed stream system because of shallow depths, extensive channelization, and poor water quality with its attendant risk to participants. Assuming that the adopted watershed water use objectives are achieved, much of the watershed stream system could support moderate boating activity limited to light, shallow draft boats such as canoes, skiffs, and rubber rafts.

The extensive vegetation, primarily hardwood forests, that once covered the entire Menomonee River watershed has been reduced to only scattered remnants of woodlands and wetlands, principally as a result of man's activities. A 1973 inventory of remaining woodland-wetland areas not protected by public ownership revealed the existence of 22 such areas. Ranging in size from about 10 to approximately 540 acres, these sites encompass only 3.2 percent of the watershed area, and about two-thirds were classified in the lowest quality category as a result of the degree of disturbance and the absence of desirable diversity. One high quality site—Bishops Woods in the City of Brookfield—was identified at the

[17] *Based on 6,138 acres of park and recreational land in the watershed, as reported in Chapter 3 of this volume, minus 230 acres of regional park and recreational land represented by the in-watershed portion of Greenfield Park, and 326 acres in Dretzka Park.*

time of the survey but has since been significantly diminished in value as a result of an office park development which is occurring within the woods. Even if the woodland portions of publicly and privately owned park, outdoor recreation and related open space sites are considered in conjunction with the unprotected woodlands in the watershed, the total amount of woodlands is very deficient when compared to the woodland standard set forth in the recommended land use objectives.

Although only remnants exist of the extensive woodland-wetland areas that once covered most of the watershed, those remnants have the potential to contribute significantly to the maintenance of the overall quality of life in the watershed. These woodland-wetland areas have scenic attributes, serve as visual and acoustic shields, are the focal point of wildlife productivity, provide desirable continuous range for wildlife, help to maintain the quality of the surface waters, have the potential to fulfill education and research functions, and can provide a setting or background for some outdoor recreational activities.

The watershed portion of the Milwaukee County Park System provides an excellent example of how continuous portions of riverine area woodlands and wetlands can be protected by public acquisition so as to fulfill many of the above functions. Inasmuch as the remaining woodlands and wetlands in the Ozaukee, Washington, and Waukesha County portion of the watershed are concentrated in riverine areas, multifunction parkways and natural areas could be acquired and carefully developed in those portions of the watershed.

The location, areal extent, and quality of wildlife habitat and, equally important, the type of wildlife characteristic of those areas are key factors in establishing the overall environmental quality of the Menomonee River watershed. A detailed inventory and analysis of watershed wildlife and their habitat were conducted in 1973. Although minimum life requirements of wildlife have disappeared over much of the watershed, 100 distinct wildlife habitat areas of high, good, moderate, and low quality were identified throughout the watershed. Most of the sites were relatively small in that 84 of the wildlife habitats were 160 acres or less in extent. Only three high quality wildlife habitats remain in the watershed—the Tamarack Swamp and Feld Maple Woods in the Village of Menomonee Falls and the Germantown Swamp in the northeast corner of the Village of Germantown. These three high quality wildlife habitat sites as well as most of the 22 good quality sites are all concentrated in the upper rural or less developed areas of the watershed.

Pollution-tolerant fish dominate the watershed's fish population, although a significant improvement in the composition may be expected in the lower portions of the watershed upon achievement of the adopted water use objectives. A variety of amphibians and reptiles, most of which are considered vital components in the ecologic system, exist in the watershed but many species are being dispersed and reduced in number as a result of the urbanization process. A surprisingly large number and variety of birds—over 230 species—are found in the watershed either as migrants or as breeders including game birds such as the pheasant and partridge, waterfowl such as the mallard and teal, and songbirds such as cardinals and warblers. Less desirable birds found in the watershed include the English sparrow and pigeons, both of which thrive in the urban areas and replace those species less tolerant to urban conditions.

A variety of mammals exists within the watershed ranging in size from the northern whitetailed deer to the pygmy shrew. Urbanization has and continues to diminish the quantity and quality of much of the watershed's mammal population because of the demanding habitat requirements of most species. Certain mammals such as the cottontail rabbit, the gray squirrel, and bats are compatible with the urban environment provided some semblance of natural habitat remains.

The wildlife that remains within the Menomonee River watershed, although significantly reduced in quantity and quality relative to presettlement conditions, also has the potential to contribute significantly to the overall quality of life in the watershed if selected portions are protected and properly managed.

The Milwaukee County Park System, with its linear and continuous parkways, provides an example of how the above wildlife values can become an integral part of the urban scene. This parkway system provides continuous range linking the urban and rural areas of the watershed, contains a variety of wildlife, and is readily accessible to the urban residents in the lower portions of the watershed. Opportunities for similar publicly owned linear and continuous wildlife reserves still remain in the riverine areas of the Ozaukee, Washington, and Waukesha County portions of the watershed.

The Menomonee River watershed may be divided into eight ecologic units to permit an integrated analysis of the watershed's natural resource base and a better understanding of its potential for maintaining and improving environmental quality. This unit-by-unit analysis clearly indicates that the quantity, quality, and diversity of wildlife habitat, fish life, and woodland-wetland areas declines in a generally northwest to southeast direction across the basin; that is, the loss of natural resource values of the ecologic units is directly correlated with the degree of urbanization.

The watershed study included an analysis of outdoor recreational demand exerted by watershed residents and the ability of the existing and potential recreational lands within the watershed to meet those demands. The availability of and participation in outdoor recreational activities is an important index of the quality of life enjoyed by the residents of an urban and urbanizing area like the Menomonee River watershed. The two factors that are most likely to influence outdoor recreational demand of watershed residents are seasonal variation, with the summer period being the most critical for most activities, and urbanization with attendant changing life styles.

A 1970 outdoor recreational activity survey conducted by the Wisconsin Department of Natural Resources was used to estimate the existing and year 2000 outdoor recreational activity demand by watershed residents. Seventeen categories of major outdoor recreational activities were utilized, and the demand for each was expressed in terms of participant-days on a peak weekend day during the season appropriate for the particular activity. The four most popular outdoor recreational activities are swimming, picnicking, fishing, and target shooting. Water-based activities account for 43 percent of the outdoor recreational activity demand with the remainder being categorized as land-based.

Area-use standards were applied to the outdoor recreational activity demand to determine the amount of recreational land required to meet the demands of watershed residents for the five recreational activities requiring intensive site development—picnicking, swimming, snow skiing, golfing, and camping. A comparison of the required land to the existing lands revealed that there are sufficient swimming and picnicking lands and facilities and golf courses to meet the existing and forecast demand for these three activities through the year 2000. However, it is desirable to develop some additional swimming and picnicking sites and golf courses in the northern portions of the watershed to facilitate ease of access to such facilities by residents of the newly urbanizing areas of the basin. The watershed is deficient in meeting the forecast camping demand, and there is little potential for developing quality camping areas with the capacity to satisfy camping demand. The Menomonee River watershed also is deficit in snow skiing facilities but enough potential sites exist for development of the necessary additional facilities by either private interests or public entities.

It may be assumed that the demands for most of the remaining 12 outdoor recreational activities can be satisfied either on recreational backup lands or on public rights-of-way. The three exceptions are motor boating, water skiing, and target shooting. Surface water resources from a physical standpoint are not capable of supporting motor boating and water skiing, whereas the urban and urbanizing nature of the watershed is not conducive to target shooting.

Chapter X

WATER LAW

INTRODUCTION

In any sound planning and engineering effort, it is necessary to investigate the legal as well as the physical and economic factors affecting the problem under consideration. In comprehensive watershed planning, the law can be as important as the hydrology of the basin or the benefits and costs of proposed water quantity and quality control facilities in determining the ultimate feasibility of a given watershed plan. If the legal constraints bearing on the planning problem are ignored during plan formulation, serious obstacles may be encountered during plan implementation. This is particularly true in the area of water resources.

Water constitutes one of the most important natural resources. It is essential not only to many of the primary economic activities of man but also to life itself. The available quantity and quality of this important resource are, therefore, among the most vital concerns of a host of interest groups representing agriculture, commerce, manufacturing, conservation, and government. Not only are rights to availability and use of water of vital concern to a broad spectrum of public and private interest groups, but the body of law regulating these rights is far from simple or static. Moreover, changes in this complex, dynamic body of law will take place even more rapidly as pressure on regional, state, and national water resources becomes more intense. For example, in the last year, the Wisconsin Supreme Court in landmark cases expressly overruled the historic common law doctrine on both groundwater law[1] and diffuse surface water law,[2] finding the historic doctrines in these areas no longer applicable to modern water resource problems and conflicts.

To provide the basis for a careful analysis of existing water law in southeastern Wisconsin, a survey was undertaken of the legal framework of public and private water rights affecting water resources management, planning, and engineering. This undertaking was one of the important work elements of the first comprehensive watershed planning program in the Southeastern Wisconsin Region, that for the Root River watershed. The findings of this initial legal study, conducted under the direction of the late Professor J. H. Beuscher of the University of Wisconsin Law School, were set forth in the initial edition of SEWRPC Technical Report No. 2, Water Law in Southeastern Wisconsin, published in January 1966. This initial water law study included an inventory of existing powers and responsibilities of the various levels and agencies of government involved in water resources management, as well as a discussion of the structure of public and private water rights, which must necessarily be considered in the formulation of a comprehensive watershed plan. Because of the dynamic nature of water law, including not only case law decisions but increasing intervention into the area of water law by both the U. S. Congress and the Wisconsin Legislature, the Commission in 1975 updated the findings of the legal study set forth in SEWRPC Technical Report No. 2. The results of this updated study of water law have been set forth in the second edition of SEWRPC Technical Report No. 2, Water Law in Southeastern Wisconsin.

This chapter consists of a summary presentation of the more detailed information concerning water law set forth in the technical report. The major purpose of this chapter is to summarize the salient legal factors bearing on the water related problems of the Menomonee River watershed and on plans for their solution, thereby laying the basis for intelligent future action. It does not, however, dispense with the need for continuing legal study with respect to water law, since this aspect of the overall watershed planning effort becomes increasingly important as plan proposals reach the implementation stage.

Attention in this chapter is focused first on those aspects of water law generally pertinent to the planning and management of the water resources of any watershed in southeastern Wisconsin. Included in this section are a general summary of water law; a discussion of the machinery for water quality management at the federal, State, and local levels of government; a discussion of floodland regulation and the construction of flood control facilities by local units of government; and a discussion of the development and operation of harbors. Finally, more detailed consideration is given to those aspects of water law that relate more specifically to the problems of the Menomonee River watershed, including inventory findings on state water regulatory permits and state water pollution abatement orders and permits.

GENERAL SUMMARY OF WATER LAW

Legal Classification of Water

In dealing with water resources and water regulation, Wisconsin's Supreme Court and the State Legislature traditionally have recognized the following five distinct legal divisions of water:

1. Surface water in natural watercourses—water occurring or flowing in lakes, ponds, rivers, and natural streams, the limits of which are generally marked during normal water conditions by banks or natural levees.

[1] *State v. Michels Pipeline Construction, Inc.*, 63 Wis. 2d 278 (1974).

[2] *State v. Deetz*, 66 Wis. 2d 1, 224 N.W. 2d 407 (1974).

2. Diffuse surface water—water which is diffused over the ground from falling rain or melting snow and that occurs or flows in places other than natural watercourses; that is, not confined by banks.

3. Groundwater in underground streams—defined as water occurring or flowing in a well-defined underground channel, the course of which can be distinctly traced. It is doubtful that such identifiable underground channels exist within the watershed, or, indeed, within the Region.

4. Percolating groundwater—defined as water which seeps, filters, or percolates through underground porous strata of earth or rock, but without a definite channel.

5. Springs—natural discharge points for groundwater from either an underground stream or percolating water.

It should be emphasized that the foregoing are somewhat unnatural divisions of water based upon where water happens to occur momentarily. In nature, groundwaters and surface waters are often difficult to separate reasonably.

Principal Divisions of Water Law
Based upon the foregoing legal classification of water, three principal divisions of water law may be identified: riparian and public rights law, groundwater law, and diffuse surface water law. Riparian and public rights law applies to the use of surface water ocurring in natural rivers, streams, lakes, and ponds. This body of law has evolved as common law based upon not only the decisions of the courts on a case-by-case basis but also upon the customs and usages of the people. The common law base has been augmented by legislation delineating "public rights" in those watercourses which are navigable. Groundwater law applies to the use of water occurring in the saturated zone below the water table. Diffused surface water law applies to water draining over the surface of the land. The latter body of law in Wisconsin relates not only to water use but to conflicts that arise in trying to dispose of this surface water. Groundwater and diffused surface water law both have evolved largely by court interpretation as common law and, as noted below, both bodies of law have undergone significant changes in the last year.

The Wisconsin Supreme Court has developed many of the legal rules covering all three of these divisions of water law, case by case, over a long period of time. In addition, the State Legislature from time to time has enacted statutes affecting some of these divisions. Reference also must be made to the important body of administrative law made by state agencies in the day-to-day administration of State water statutes. Examples are rules adopted to implement statutes governing the issuance of permits by the Wiconsin Department of Natural Resources for irrigation and mining purposes; for dams; for the fixing of bulkhead and pierhead lines; and for the construction of bridges, piers, docks, and other shoreline improvements along navigable watercourses. The Wisconsin Department of Natural Resources also is authorized to fix levels for navigable lakes and flow rates for navigable streams.

Riparian and Public Rights Law: Rights in water may be designated as private and public. Industrial, cooling, irrigation, and power generation are examples of private rights, while fishing, boating, and swimming are examples of public rights. It is essential, however, to recognize that public and private rights to use water are interrelated and that, while these labels may be convenient for classification purposes, they tend to encourage oversimplification. In certain circumstances, it may be more in the public interest to promote a private use even though the conventional public rights are consequently limited. Conflicts also may arise among various segments of the public regarding which of the public rights is paramount, particularly where the exercise of one public right may seriously affect the possibility of exercising another.

Riparian Rights: Riparian doctrine, which in Wisconsin forms the primary basis of the law governing the use of surface water in natural watercourses, provides that owners of lands that adjoin a natural watercourse have rights to co-share in the use of the water so long as each riparian is reasonable in his use. Obviously, the definitions of the terms "reasonable" and "natural watercourse" are critical to the application of riparian law.

Surface Watercourses: The Wisconsin Supreme Court requires, that in order to constitute a watercourse, there must be

> . . . a stream usually flowing in a particular direction, though it need not flow continually. It may sometimes be dry. It must flow in a definite channel, having a bed, sides, or banks, and usually discharges itself into some other stream or body of water. It must be something more than a mere surface drainage over the entire face of a tract of land, occasioned by unusual freshets, or other extraordinary causes. It does not include the water flowing in the hollows or ravines in land, which is the mere surface water from rain or melting snow, and is discharged through them from a higher to a lower level, but which at other times are destitute of water.[3]

Although riparian rights sometimes are conceived to attach to artificial watercourses, usually they are restricted to watercourses which are natural in origin. The term watercourse comprehends springs, lakes, or marshes in which the stream originates or through which it flows. Natural lakes or ponds which are not part of a stream system are, nevertheless, waters to which riparian rights

[3] *Hoyt v. City of Hudson, 27 Wis. 656 (1871). A lengthy definition distinguishing watercourse from diffuse surface water is contained in Fryer v. Warne, 29 Wis. 511 (1872).*

also are attached. Clearly, the Menomonee River and its major tributaries meet the definitional requirements of a watercourse; and riparian law applies.

Natural Flow and Reasonable Use: With respect to the relative rights of riparian land owners along a watercourse, there is language in Wisconsin cases to the effect that a riparian owner is entitled to have a watercourse flow through his land without material diminution or alteration—the so-called "natural flow" doctrine. Strict application of such a rule would preclude effective use of the water for other than domestic needs.

In those cases in which the Wisconsin Supreme Court used "natural flow" language, however, the court was merely indulging in preliminary observations, for in each such case the language subsequently was modified and limited, and the "reasonable use" rule applied to the particular situation presented. Therefore, it is an abstract statement to say that in Wisconsin riparian owners are entitled to the continuous full and natural flow of a watercourse for, in the words of the Wisconsin Supreme Court:

> To say, therefore, that there can be no obstruction or impediment whatsoever by the riparian owner in the use of the stream or its banks, would be in many cases to deny all valuable enjoyment of this property so situated. There may be, and there must be, allowed of that which is common to all a reasonable use.[4]

Thus, in Wisconsin the reasonable use doctrine qualifies the strict right to the natural flow of a stream or the natural level of a lake. This use right is not a right in the sense that a riparian proprietor owns the water running by, or over, his land. It is a right called "usufructuary" in that the riparian may make a reasonable use of the water as it moves past.

The term "reasonable use" implies that a question of fact must be resolved in each case, and the Wisconsin Supreme Court has recognized the concept as a flexible one in conceding that no rule can be stated to cover all possible eventualities. The court has said, in determining what is a reasonable use, that:

> Regard must be had to the subject matter of the use, occasion, and manner of its application, its object, extent and the necessity for it, to the previous usage, and to the nature and condition of the improvements upon the stream; and so also the size of the stream, the fall of the water, its volume, velocity and prospective rise and fall, are important elements to be considered.[5]

Thus, it may be concluded that a user's utilization of water must be reasonable under all the circumstances; and he may meet this test despite substantial interference with the natural flow of a watercourse, for it is recognized that any rule preventing all, or almost all, interference with the flow would needlessly deprive riparian proprietors of much of the value of the stream and prevent its utilization for any beneficial purpose. In this respect, it should be recognized that, wherever the Department of Natural Resources, at the request of one or more riparians and after notice and hearing, fixes the level of a lake or grants a permit for the construction or enlargement of a dam or pier, other riparians will probably have a difficult time establishing that the permitted uses are unreasonable. A permit to irrigate imposes a similar burden of proof upon co-riparians who may later complain of unreasonable use. In addition, a water user may acquire a firm right to a specific quantity of water by adverse use (prescription) over a long period of time, usually 20 years, or by contract with co-riparians.

Under Section 30.19 of the Wisconsin Statutes, the construction or enlargement of any artificial waterway is prohibited without the permission of the Wisconsin Department of Natural Resources where the purpose of such enlargement is an ultimate connection with an existing navigable stream or lake or where any part of such artificial waterway is located within 500 feet of the ordinary high water mark of an existing navigable stream or lake. Authorization is required not only for the construction of an artificial waterway within 500 feet of navigable waters, but also for the connection of any waterway with an existing body of navigable water and for the removal of top soil from the banks of navigable streams and lakes. Public highway construction, improvements related to agricultural uses of land, and improvements within counties having a population in excess of 500,000 are excepted from these provisions and thus do not require permission from the Wisconsin Department of Natural Resources.

Riparian Land: The Wisconsin Supreme Court has never defined the term "riparian land" with precision. It is clear, however, that to be riparian, land must adjoin the watercourse; and probably it must lie within the watershed of that watercourse. It is also held in Wisconsin that riparian rights rest upon ownership of the bank or shore in lateral contact with the water, not upon title to the soil under the water.

The Wisconsin Department of Natural Resources, in administering the issuance of permits to irrigators pursuant to Section 30.18 of the Wisconsin Statutes, has limited riparian land to that land bordering a lake or stream which has been in one ownership in an uninterrupted chain of title from the original government patent. This is similar to the so-called "source of title" test. Under it, the conveyance of a back parcel of riparian land to another renders the transferred parcel nonriparian unless the deed provides otherwise; and it remains so even though the original riparian owner subsequently repurchases it. Presumably, also, if the purchaser of the back parcel also buys the tract touching the water, the back

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[4] *A. C. Conn Company v. Little Swamico Lumber Manufacturing Company, 74 Wis. 652, 43 N.W. 660 (1889).*

[5] *Timm v. Bear, 29 Wis. 254 (1871).*

parcel continues to be nonriparian. Thus, a riparian cannot assemble nonriparian land and make it riparian. A nonriparian cannot convert his land to riparian status by buying a riparian tract. Under this rule there is a continual dwindling of riparian land.

Nonriparian Use: Nonriparian use occurs when a riparian uses an excessive quantity of water beyond his reasonable co-share; when a riparian uses water on nonriparian lands which he owns or controls; or when a nonriparian takes water from a watercourse, usually with permission or by grant from a riparian, for use on nonriparian land. The latter situation deserves some attention since, as a practical matter, such problems could arise in the Menomonee River watershed because of possible withdrawals for municipal, irrigation, or industrial use.

It is not known whether the Wisconsin Supreme Court would treat municipal use from a natural watercourse differently from private use. Surprisingly, most states that have spoken on the subject refuse to do so. They treat a municipal water utility as just another water user and point with disapproval to the distribution of water to nonriparian customers of the utility. The courts insist that, if downstream riparians are hurt by the municipal diversion, the utility must acquire by eminent domain or otherwise the requisite downstream rights.

The irrigator who wants to use water from a stream must obtain a permit under the Wisconsin irrigation permit law, Section 30.18 of the Wisconsin Statutes. He must limit his irrigation to riparian and contiguous lands. Permits are not required of commercial or industrial water users as a precondition to withdrawal from a watercourse. Whether such users can use water on nonriparian land is an unresolved question, although the Wisconsin Supreme Court in Munninghoff v. Wisconsin Conservation Commission has said:

> It is not within the power of the state to deprive the owner of submerged land of the right to make use of the water which passes over his land, or to grant the use of it to a nonriparian. [6]

The Wisconsin Attorney General has stated that:

> Previous decisions in other states have held that a riparian owner could make any reasonable use of the water even on nonriparian land providing there was no unreasonable diminishment of the current and no actual injury to the present or eventual enjoyment of the property of the lower riparian owner.[7]

Public Rights in Navigable Water: When a riparian uses navigable water, his uses may impinge upon public rights in the water. Private water uses are often completely consistent with the exercise of public rights in navigable streams and lakes, but serious conflicts may arise between private riparians and those seeking to exercise public use of a given watercourse. In that event, in Wisconsin the public rights will likely prevail. This does not mean that private riparian rights in every case may be taken or substantially abridged without compensation, for it has long been recognized that such rights are property rights which cannot be "taken" for a public purpose without compensation.

The Wisconsin Supreme Court, however, might treat the riparian's private property right as "inherently limited" by public rights in the water. The Court might say that this limitation existed at the time the riparian acquired his private right and that he took title subject to the limitation. This line of reasoning would permit a holding that compensation need not be paid even though public uses substantially impair private use. In this respect two recent Wisconsin cases—one dealing with the statutory requirement in Section 30.18 of the Wisconsin Statutes requiring a permit for the diversion of water from lakes and streams[8] and the other dealing with the navigable waters protection law and the imposition of county shoreland zoning[9]—have found that a reasonable exercise of the police power to preserve nature from harm resulting from unrestricted human activity is a valid use of the police power resulting only in incidental damages to the riparian. Thus, it may be concluded that public rights operate as a "burden" on riparian land in the sense that a riparian may be prevented from exercising rights which conflict with the public use of a watercourse.

Definition of Navigable Waters: In order for certain public rights to attach to a body of water, the water must be navigable. The Wisconsin Supreme Court's test of navigability has moved from one of commercial transport only to include suitability for recreational boating. In early statehood, the question was whether the stream or lake could be used to float products of the country to market for a significant period during the year. The principal product floated to market in those days was the saw log, hence the so-called "saw log" test of navigability. More recently, however, the Wisconsin Supreme Court has said:

> Any stream is "navigable in fact" which is capable of floating any boat, skiff, or canoe of the shallowest draft used for recreational purposes.[10]

In order to qualify as navigable, the stream, pond, or lake clearly does not have to be capable of floating a product to market or even of floating a boat, skiff, or canoe every

[6] *255 Wis. 252 38 N.W. 2d 712 (1949).*

[7] *39 Op. Atty. Gen. 654 (1950).*

[8] *Omernick v. State, 64 Wis. 2d 6, 218 N.W. 2d 734 (1974).*

[9] *Just v. Marinette, 56 Wis. 2d 7 (1972).*

[10] *Muench v. Public Service Commission, 261 Wis. 492, 53 N.W. 2d 514 (1952).*

day of the year or every foot of its length or every acre of its surface. The Wisconsin Court, however, has not ruled on the length of time needed to establish navigability. By the recreational boating test, most natural ponds and lakes are navigable; and streams of even modest size may be navigable. Clearly, the Menomonee River and its principal tributaries are navigable by this test.

Ownership of the Land Underlying a Water Body: Determination of ownership of a stream or lake bed may have important consequences. If the bed is privately owned, removal of material from the bed may be authorized by the owner so long as there is no interference with the exercise of possible public rights to use the water and provided a permit is obtained from the Wisconsin Department of Natural Resources, under Section 30.20(1)(b) of the Wisconsin Statutes. If the bed is publicly owned, removal can only be with permission from, and payment to, the State.

Wisconsin holds that the beds of streams, whether navigable or nonnavigable, belong to the owners of the adjacent shorelands, always subject, however, to the overriding public servitude of navigation and other public rights that adhere to navigable water. Private proprietors whose lands make lateral contact with the waters of a stream own the bed to the middle or thread of that stream, regardless of whether the stream is navigable or not. The bed owner is in a position comparable to a landowner whose land is subject to a public highway easement.

Beds of natural navigable lakes are owned by the State in trust for all of the people. Private proprietors whose lands abut the waters of a natural lake have no claim to any portion of the bed. The ownership of beds underlying man-made lakes or reservoirs, caused by damming a stream or otherwise impounding a natural flow of water, remains in the hands of abutting landowners. Where the stream was navigable before it was dammed, the waters spread behind the dam are likewise navigable; thus, the privately owned bed of the reservoir in such a case seems to be subject to the same public servitude that originally applied to the undammed stream.

Groundwater Law: In 1974 in a case originating in southeastern Wisconsin, the common law doctrine affecting percolating groundwater was expressly overruled. The old rule, which was firmly established in the case of Huber v. Merkel[11] permitted a landowner to use the captured waters found beneath the surface with impunity. Under this old rule, aa landowner could do with water as he wished, to use on the overlying land or elsewhere, and even to waste. The new rule adopted by the Wisconsin Supreme Court in 1974 in light of modern day conditions provides for specific protection to users of groundwater.[12]

The challenge to the old groundwater doctrine initially set forth in the Huber case grew out of circumstances created by the installation of a Milwaukee-Metropolitan Sewerage Commissions' trunk sewer in the City of Greenfield. In accordance with its long-range plans, the Metropolitan Sewerage Commission of the County of Milwaukee contracted with Michels Pipeline Company, Inc., to install a 60-inch-diameter trunk sewer beneath the Root River Parkway. The Milwaukee County Board of Supervisors had granted a construction easement for the sewer. Because of the depth of the sewer—about 40 feet—construction called for tunneling. Frequently, such tunneling creates an inward flow of groundwater which fills the void created in the earth for the sewer. In order to overcome this problem, the standard construction practice has been to dewater the area involved during the construction period by pumping water from specially drilled wells. The net effect of this construction technique is to considerably speed up the process of tunneling and installing the sewer line, and thereby reduce the cost to the public as a whole for sewer construction. The dewatering process, however, at times has effects that are not confined to the groundwaters immediately along the tunnel course, causing also a drawdown in the surrounding area which, in turn, causes a decrease in the quantity of water available for nearby wells and occasionally produces dry wells.

In the case of the Root River Parkway trunk sewer in the City of Greenfield, the State argued that many citizens in the area had suffered private injuries as a direct result of the sewer installation and dewatering project. The relief sought by the State, however, was not to see the project discontinued but, rather, the injuries it was causing eliminated. The State argued that there would be costs generated no matter what course of action the defendants pursued and that it would be better to spread the higher costs resulting from a different construction technique to all persons benefiting from the sewerage system, rather than to place such costs upon a selected few adjacent landowners, as permitted under the groundwater law doctrine set forth in the Huber case.

When the case reached the Supreme Court level, the Court agreed with the basic arguments of the State and found that the dewatering practice by the sewer contractor constituted a public nuisance in that the neighborhoods surrounding the sewer project had been adversely affected by the dewatering. In making that finding, the Court then recognized that it would have to expressly overrule the Huber v. Merkel decision set forth around 1900, long before the need for major metropolitan sewerage systems was recognized. In overruling the Huber case, the Court noted that the basis for the common law rule embraced by the Supreme Court in the Huber case was found in the English common law developed at the time when the forces which controlled the movement of underground water were somewhat mysterious and not fully understood. As a result, it was much easier and more practical for the English courts, and subsequently the Wisconsin Court, to fashion a rule of absolute possession with no liability for injury rather than attempting to regulate a not fully understood phenomenon. The Court

[11] *117 Wis. 355, 94 N.W. 2d 354 (1903).*

[12] *See State v. Michels Pipeline Construction, Inc., 63 Wis. 2d 278 (1974).*

noted that, since the Huber case, knowledge in the scientific community, particularly in the field of hydrology, had progressed to such an extent that it was foolish to adhere to an archaic position. The Court emphasized that water systems were interdependent and that sophisticated means were available to measure the impact of drawing upon underground water and the effect that it has on the water table. Moreover, the Court analogized that there was little justification for property rights in groundwater to be considered absolute, while such rights in surface water cases were subjected to the doctrine of reasonable use. As a result, the Court felt compelled to overrule Huber v. Merkel.

In seeking to find a suitable rule to replace the one overturned, the Court analyzed several possible doctrines. These included: 1) the English rule, or common law rule of absolute ownership, which is similar to the doctrine set forth in the Huber case except that a landowner would be liable for damages caused his neighbors if it could be shown that withdrawal was motivated by malicious intent; 2) the reasonable use doctrine which, used in this context, has a very limited or restricted meaning since, under this rule, only a wasteful use of water that actually causes harm is unreasonable; 3) the correlative rights doctrine, which calls for an apportionment of available underground water determined by the amount of water available that may be reasonably used under the circumstances, a doctrine that has been applied by many courts where there is not sufficient groundwater to supply all needs; and 4) the so-called American rule, which calls for liability on the part of a landowner who withdraws water if the withdrawal of the water causes unreasonable harm through lowering the water table or reducing artesian pressure. Under the American rule, there is a presumption that groundwater is plentiful and that a privilege exists to use the water beneath the land. Of particular importance in the application of the American rule is the determination of reasonable use and, in so doing, determining who shall bear the burden of costs, it being considered usually reasonable to give equal treatment to persons similarly situated and to subject each to similar burdens.

After careful consideration of these doctrines, the Court decided to adopt the American rule for application in the Michels case and for prospective application to future groundwater litigation. An example supplied by the Court illustrates the applicability of the American rule. This example involves a situation where a farmer drills a well which initially is sufficient for irrigation but subsequently becomes inadequate because of other farmers in the area using the same groundwater for the same purpose—irrigation. The cost for deepening the first farmer's well because of the lowering of the water table under the American rule would be assumed by the first farmer, since in this instance all individuals using the same groundwater are similarly situated. If, however, another farmer lowered the water table for another use, such as stock watering, or if a municipality lowered the water table to supply domestic water, the rule would place liability on them for the damage caused the first farmer. In essence, the rule provides that utilization of groundwater for wholly new purposes or for substantial increases in an existing use will subject the new user to liability if the prior users suffer injury. In the Michels case, then, the utilization of the groundwater for dewatering purposes to permit sewer construction constituted a wholly new use that was found to cause damage to the prior users, those neighboring residences who had relied upon the groundwater for a source of domestic supply.

Court adoption of the American rule on groundwater law probably will lead to greater precautions being taken, including more adequate planning and engineering prior to the installation of new wells. The result should ensure a more equitable sharing of the costs involved in groundwater use by those who actually benefit from the improvements.

From a legislative point of view, the Wisconsin Legislature has intervened in groundwater use in only one way. It has required that a permit be obtained from the Wisconsin Department of Natural Resources by anyone who desires to develop or redevelop a well or well field with facilities for withdrawal of water at a rate of 100,000 gallons per day (70 gallons per minute) or more.[13] The statute, however, is severely restricted in its application. The Department is limited in its determination to whether the withdrawal will adversely affect or reduce the availability of water to any public utility. Interference with a nonpublic utility well is not statutory grounds for denial of a permit.

Diffuse Surface Water Law

In another recent landmark case, the Wisconsin Supreme Court has adopted a new rule or doctrine with respect to diffuse surface water law. Until late 1974, Wisconsin had followed the "common enemy" doctrine in determining the propriety of interfering with diffuse surface waters. Basically, that rule permitted private land owners who were seeking to improve their land to fight as a common enemy the diffuse surface water in a particular drainage shed. Such action could be carried out regardless of the harm caused to others as long as it did not involved tapping a new drainage shed. The basis for embracing this doctrine developed in the mid-19th and 20th centuries, and was based upon a policy of facilitating urban growth and accompanying economic development. The allowable practices under the common enemy doctrine often caused severe injuries, however, to those with the misfortune of being on the receiving end of a new drainage pattern. Their injury became compounded when no recovery was permitted under the law.

In 1974 the Wisconsin Supreme Court felt that the common enemy doctrine was not a realistic rule for contemporary times. In the case of State v. Deetz,[14] the Court elected to abandon the common enemy doctrine in favor of the "reasonable use" rule. The decision in this case was perhaps foreshadowed by the decision in the Michels case dealing with groundwater as discussed

[13] *Wisconsin Statutes 144.025(2)(e).*

[14] *66 Wis. 2d 1, 224 N.W. 2d 407 (1974).*

above, since it, too, reflects an attempt to bring the common law in harmony with the needs of contemporary society. In the Deetz case, the State brought an action against a property developer for the purpose of enjoining the developer from causing material to be deposited on an adjacent road and in Lake Wisconsin. The Deetzes had purchased lands overlooking Lake Wisconsin and had developed the lands for residential use. In so doing, the Deetzes caused a substantial increase in the amount of soil being carried from the bluff by diffuse surface waters. The end result was to create substantial sand deltas in Lake Wisconsin and to cover the road at the base of the bluff by sand up to eight inches deep.

In considering this case the Wisconsin Supreme Court, while agreeing that the trial court in dismissing the State complaint had properly applied the common enemy rule, agreed with the State contention that the common enemy doctrine no longer met the realities of contemporary society. Accordingly, the Court decided to adopt the reasonable use rule, applying it to the Deetz case and prospectively to diffuse surface water litigation. The reasonable use rule is founded in basic concepts of nuisance law. The rule states that one is subject to liability when one invades another's lands (in this case the invasion is not a trespassory invasion but rather an invasion caused by diffuse surface waters) when the invasion is 1) either intentional and unreasonable, or 2) unintentional and caused by negligent or reckless conduct. The Court emphasized that the new rule would apply not only to those nuisances caused by private individuals but by the public as well.

The critical determination in the application of this rule centers on the unreasonableness of the act creating the harm. This question is one of fact to be decided on a case by case basis. The rule states that an act is unreasonable if the gravity of the harm caused by the act outweighs the utility of the actor's conduct, or if the harm caused by the act is substantial and the financial burden of compensating for the harm does not render infeasible the continuation of the act. In determining the gravity of the harm, the rule provides that there are several factors to be considered, including the extent of the harm; the character of the harm; the social value which is attached to the type of use harmed; the suitability of the particular use harmed to the character of the locality; and the burden on the person harmed in taking steps to avoid the harm. In effect, this latter factor indicates that persons living in society must make a reasonable effort to adjust their use of the land to those of their fellowmen before they can complain of being interfered with. The rule further provides that several factors should be weighed in determining the utility of the conduct which causes the harm. These factors include the social value which the law attaches to the primary purpose of the conduct; the suitability of the conduct to the character of the locality; whether it is impractical to prevent or avoid the harm if the conduct or activity is maintained; and whether it is impractical to maintain the conduct or activity if it is required to bear the cost of compensating for the harm.

Since in the Deetz case the changed pattern of diffuse surface waters involved the deposition of materials on public roads and in navigable waters, the application of the reasonable use rule involved a violation of a public trust and thus constituted a public nuisance action. Obviously, because of the weighing process inherent in the application of the reasonable use rule, it will be easier to find an unreasonable use when a public nuisance action is undertaken as opposed to a private nuisance action. A private individual injured under relatively similar facts will undoubtedly have a heavier burden to bear in a private nuisance action than in a public nusiance action because of the social utility involved in most public actions.

The application of the new rule to situations involving governmental units is somewhat unclear, primarily because of the doctrine of soverign immunity. Until the Deetz case, the common law in Wisconsin was quite explicit in not allowing damages where a municipality was involved in constructing streets and sewers, going beyond even the common enemy doctrine by allowing the municipality to tap new watersheds which affect the flow of surface waters. Under this common law, private landowners could not sue for damages caused by a municipality changing the natural flow of diffuse surface water or increasing the volume of such surface water. Absent the overriding factor of soverign immunity, interesting fact situations could arise in the application of the reasonable use rule, involving damages to the public interest caused by public conduct. In such cases, the equations for weighing the harm caused the public trust against the utility of the public conduct would involve actions designed to benefit the public versus injuries to the public interest; and if the fact situation of Deetz were reversed, that is, if the public had through land development caused harm to private interests, the implication of the reasonable use rule would clearly favor the public enterprise. It is likely in situations like this that the Court would rate the social utility of the public development very high against the invasion of private interests and the causing of private harm.

Statutes affecting diffuse surface water are very limited. In Section 88.87 of the Wisconsin Statutes, the Legislature has recognized that the construction of highways and railroads will inevitably affect the drainage patterns of surface waters. Accordingly, this Statute provides that a public body or a railroad company, in laying out and constructing highway and railroad grades must not impede the general flow of surface water in any unreasonable manner so as to harm adjacent land owners. The legislation also imposes similar restrictions on landowners and users of land in adversely affecting highways and railroad grades through private drainage actions. Basically, the test employed by the Statutes is whether the actions taken which affect surface water drainage are reasonable and consistent with sound engineering practices, a statutory test not unlike the reasonable use rule set forth in the Deetz case.

WATER QUALITY MANAGEMENT

Inasmuch as the Menomonee River watershed study is intended to deal with problems of water quality, as well as water quantity, and to recommend water use objectives and water quality standards for the Menomonee River basin, it is necessary to examine the existing and potential legal machinery through which attainment of water quality goals may be sought at various levels of government and through private action.

Federal Water Quality Management

The federal government has long been involved in water quality management efforts, although it is only in relatively recent years that the U. S. Congress has acted to secure the establishment of water use objectives and supporting standards for navigable waters. The 1899 Refuse Act prohibited the discharge of any refuse matter of any kind, other than that flowing from streets and sewers, into any navigable waters of the United States, or tributaries thereto, without first obtaining a permit from the Secretary of the Army. The Secretary was directed to make a specific finding that the discharge of any refuse matter would not adversely affect anchorage and navigation; no finding on water quality was, however, required. This act and the permits issued thereunder were largely ignored until enactment of the federal Environmental Policy Act of 1969, which required all federal agencies to consider the environmental impact in the administration of all public laws, and the Water Quality Improvement Act of 1970, which required applicants for federal permits to file a certification from the appropriate state that the proposed discharge would not violate any applicable state-adopted water quality standard.

A broader federal approach to water quality management began with the passage of the Federal Water Pollution Control Act on June 30, 1948. With the passage of this Act, the federal government began to take effective steps toward controlling and preventing pollution of the navigable waters of the United States. Initially, the Act was primarily directed at establishing a federal grant-in-aid program for the construction of publicly-owned waste treatment facilities. In the mid-1960's, requirements were added relating to the establishment of interstate water quality standards. The Act was substantially revised by the Federal Water Pollution Control Act Amendments of 1972, enacted into law on October 18, 1972. In general, the revised Act provides for an increased emphasis on enhancing the quality of all of the navigable waters of the United States, whether interstate or intrastate, and further places an increased emphasis on planning and on examining alternative courses of action to meet stated water use objectives and supporting water quality standards. The Act declares it to be a national goal to eliminate the discharge of pollutants into the navigable waters of the United States by 1985; that, wherever obtainable, an interim goal of water quality be achieved by 1983 providing for the protection and propagation of fish and natural wildlife and for human recreation in and on the water; that substantial federal financial assistance be provided to construct publicly-owned waste treatment works; and that areawide waste treatment management planning processes be developed and implemented to assure adequate control of sources of pollutants within each state. The requirements of the Act may be categorized under the following headings; water quality standards and effluent limitations, pollutant discharge permit system, continuing statewide water quality management planning processes, areawide waste treatment planning and management, and waste treatment works construction. In the following discussion, attention is focused on these relevant portions of the Federal Water Pollution Control Act, as well as on the requirements of the National Environmental Policy Act of 1969.

Water Quality Standards and Effluent Limitations: Since 1965, the Federal Water Pollution Control Act has required states to adopt water use objectives and supporting water quality standards for all interstate waters. The Act as revised in 1972 incorporates by reference all existing interstate water quality standards and requires for the first time the adoption and submittal to the U. S. Environmental Protection Agency (EPA) for approval of all intrastate water use objectives and supporting water quality standards. Wisconsin, through the Natural Resources Board and the Department of Natural Resources, has adopted the required interstate and intrastate water use objectives and supporting water quality standards. These objectives and standards as related to streams and watercourses in the Menomonee River watershed are discussed below. Under the new federal law, state governors are required to hold public hearings every three years for the purpose of reviewing the adopted water use objectives and supporting water quality standards and, in light of such hearings, appropriately modifying and readopting such objectives and standards.

In addition to water use objectives and standards, the Act requires the establishment of specific effluent limitations for all point sources of water pollution. Such limitations must require the application of the best practicable water pollution control technology currently available, as defined by the EPA Administrator. In addition, any waste source which discharges into a publicly-owned treatment works must comply with applicable pretreatment requirements, also to be established by the EPA Administrator. By July 1, 1977, all publicly-owned treatment works must meet effluent limitations based upon a secondary level of treatment and must apply the best applicable waste treatment knowledge in so doing. In addition to these uniform or national effluent limitations, the Act further provides that any waste source must meet any more stringent effluent limitations as required to implement any applicable water use objective and supporting standard established pursuant to any state law or regulation or any other federal law or regulation.

Pollutant Discharge Permit System: The Federal Water Pollution Control Act, as revised in 1972, also establishes a national pollutant discharge elimination system. Under this sytem the EPA Administrator, or a state upon approval of the EPA Administrator, may issue permits for the discharge of any pollutant, or combination of pollutants, upon condition that the discharge will either meet all applicable effluent limitations or such additional conditions as are necessary to carry out the provisions of the Act. All such permits must contain conditions to assure compliance with all of the requirements of the Act, including conditions on data and information collection and reporting. In essence, the Act provides that all these discharges into navigable waters must obtain a federal permit or, where a state is authorized to issue permits, a state permit. The intent of the permit system is to include in the permit, where appropriate, a schedule of compliance which will set forth the dates by which various stages of the requirements imposed in the permit shall be achieved. As discussed below, Wisconsin has an approved permit system operating under the national pollutant discharge elimination system.

Continuing Statewide Water Quality Management Planning Process: The new federal Water Pollution Control Act provides that each state must have a continuing planning process consistent with the objectives of the Act. States are required to submit a proposed continuing planning process to the EPA Administrator for his approval. The Administrator is prohibited from approving any state discharge permit program under the pollutant discharge elimination system for any state which does not have an approved continuing planning process.

The state continuing planning process must result in water quality management plans for the navigable waters within the state. Such plans must include at least the following items: effluent limitations and schedules of compliance to meet water use objectives and supporting water quality standards; the elements of any areawide wastewater management plan prepared for metropolitan areas; the total maximum daily load for pollutants for all waters identified by the state where the uniform or national effluent limitations are not stringent enough to implement the water use objectives and supporting water quality standards; adequate procedures for revision of plans; adequate authority for intergovernmental cooperation; adequate steps for implementation, including schedules of compliance, of any water use objectives and supporting water quality standards; adequate control over the disposition of all residual waste from any water treatment processing; and an inventory and ranking in order of priority of needs for the construction of waste treatment works within the state.

In effect, the state planning process is designed to result in the preparation of comprehensive water quality management plans for natural drainage basins or watersheds. Such basin plans, however, are likely to be less comprehensive in scope than the comprehensive watershed plans prepared by the Regional Planning Commission. The statewide planning process is largely envisioned as one of synthesizing the various basin, watershed, and regional planning elements prepared throughout the State by various levels and agencies of government. The state planning process should become the vehicle for coordinating all state and local activities directed at securing compliance with the requirements of the Federal Water Pollution Control Act.

Areawide Waste Treatment Planning and Management: Section 208 of the Federal Water Pollution Control Act, as revised in 1972, provides for the development and implementation of areawide waste treatment management plans. Such plans are intended to become the basis upon which the EPA approves grants to local units of government for the construction of waste treatment works. The Act envisions that the Section 208 planning process would be most appropriately applied in the nation's metropolitan areas which, as a result of urban and industrial concentrations and other development factors, have substantial water quality control problems. Accordingly, the Act envisions the formal designation of a Section 208 planning agency for substate areas that are largely metropolitan in nature and the preparation of the required areawide water quality management plan by that agency within a two-year planning period.

Any areawide plan prepared under the Section 208 planning process must include at least the following elements:

1. The identification of waste treatment works necessary to meet the anticipated municipal and industrial waste treatment needs for the area for a 20-year period. This identification must include an analysis of alternative waste treatment systems, an identification of any requirements for the acquisition of land for treatment purposes, an identification of any necessary wastewater collection and urban storm water drainage systems, and the development of a program to provide the necessary financial arrangements for the development of any treatment works.

2. The establishment of construction priorities and time schedules for all treatment works included in the plan.

3. The establishment of a regulatory program to provide for the location, modification, and construction of any facilities within the planning area which may result in pollutant discharges and to ensure that any industrial and commercial wastes discharged into any treatment works meet applicable pretreatment requirements.

4. The identification of all agencies necessary to construct, operate, and maintain the facilities included within the plan and to otherwise carry out the recommendations in the plan.

5. The identification of the measures necessary to carry out the plan, including financing; the period of time necessary to carry out the plan; the cost of carrying out the plan; and the economic, social, and environmental impact of carrying out the plan.

6. The identification of agriculturally and silviculturally related nonpoint sources of pollution and the procedures and methods, including land use controls, necessary to control to the maximum extent feasible such pollution sources.

7. The identification, as appropriate, of all mine-related sources of pollution, construction-related sources of pollution, and salt water intrusion, and the methods and procedures to control to the maximum extent feasible such pollution point sources.

8. Recommendations for the control of the disposition of all residual wastes generated in the planning area which may affect water quality, such as sludge.

9. The establishment of a process to control the disposal of pollutants on land or in subsurface excavations.

All areawide waste treatment management plans must be updated annually and certified annually by the state governor to the EPA Administrator as being consistent with any applicable basin plans prepared under the continuing statewide water quality management planning process.

On September 27, 1974, the seven-county Southeastern Wisconsin Region and the Southeastern Wisconsin Regional Planning Commission were formally designated as a Section 208 planning area and planning agency pursuant to the terms of the Federal Water Pollution Control Act. This designation was made after a public hearing concerning the matter held jointly by the Wisconsin Department of Natural Resources and the SEWRPC on June 18, 1974. On December 26, 1974, the Administrator of the U. S. Environmental Protection Agency formally approved the designation and authorized the Regional Planning Commission to proceed with the preparation of an application for federal funds in support of the conduct of the proposed Section 208 areawide water quality and management planning program for the Region. On March 6, 1975, the Regional Planning Commission authorized the preparation of the necessary study design for the proposed Section 208 planning program and acted to create a new Technical and Citizens Advisory Committee on Areawide Water Quality Planning and Management to provide for guidance in preparation of the study design and the conduct of the actual study. The necessary study design was completed in April 1975 and served to support a federal grant application by the Commission for Section 208 planning funds. On December 26, 1975, the EPA approved the Commission's application and awarded the Commission a federal planning grant to conduct the proposed Section 208 planning program. The program was then mounted and is scheduled to be completed by January 1, 1978.

In general, the Commission expects the Section 208 water quality planning and management program for southeastern Wisconsin to be used to update, extend, and refine the previous studies and plans completed by the Commission, and in so doing to fully meet the requirements of the Federal Water Pollution Control Act. With respect to the Menomonee River watershed, it is anticipated by the Commission that any water quality-related plan recommendations set forth in the Menomonee River watershed plan will be fully integrated into and coordinated with the recommendations to be formulated under the Section 208 planning effort.

Waste Treatment Works Construction: One of the basic goals of the Federal Water Pollution Control Act is to provide for federal funding of publicly-owned waste treatment works. Such funding must be based upon an approved areawide waste treatment management plan designed to provide for control of all point and nonpoint sources of pollution. The Act further encourages waste treatment management at specific treatment works which provide for the recycling of potential pollutants; the confined and contained disposal of any pollutants not recycled; the reclamation of wastewater; and the ultimate disposal of any sludge in an environmentally safe manner.

The Act provides that the EPA Administrator may not approve any grant unless the applicant demonstrates that the sewage collection system discharging into the sewage treatment facility is not subject to excessive infiltration or clear water inflow. In addition, the EPA Administrator is required to find that alternative waste management techniques for a particular facility have been studied and evaluated and that the specific works proposed for federal assistance will provide for the application of the best practicable waste treatment technology over the life of the works. Federal funding for any grant for waste treatment works has been set at 75 percent of the construction costs. The applicant also must adopt a system of charges to assure that each recipient of waste treatment services within the applicant's jurisdiction will pay its proportionate share of the operation and maintenance costs of any waste treatment services provided. In addition, industrial users of treatment works must pay to the applicant that portion of the cost of construction which is allocable to the treatment of industrial wastes.

National Environmental Policy Act: One of the significant pieces of national legislation in recent years is the National Environmental Policy Act of 1969. This Act broadly declares that it is national policy to encourage a productive and enjoyable relationship between man and his environment; to promote efforts which will prevent or eliminate damage to the environment; and to enrich the understanding of the ecological systems and natural resources important to the nation. This Act has broad application to all projects in any way related to federal action. The mechanism for carrying out the intent of the National Environmental Policy Act of 1969 is the preparation of an environmental impact statement for each project. This statement must include documentation of the environmental impact of the proposed project; any adverse environmental effects which cannot be avoided should the project be constructed; any alternative to the proposed project; the relationship between the local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented. As discussed below, Wisconsin has a similar environmental policy accompanying state governmental action of all kinds within the State, whether or not this action is federally aided.

State Water Quality Management

Responsibility for water quality management in Wisconsin is centered in the Wisconsin Department of Natural Resources. Pursuant to the State Water Resources Act of 1965, the Department of Natural Resources acts as the central unit of State government to protect, maintain, and improve the quality and management of the ground and surface waters of the State. The only substantive water quality management authority not located in the Wisconsin Department of Natural Resources is the authority to regulate private septic tank sewage disposal systems, a function that joins general plumbing supervision as the responsibility of the Wisconsin Department of Health and Social Services, Division of Health. Attention in this section of the chapter will be focused on those specific functions of the Wisconsin Department of Natural Resources which directly bear upon water quality management and, hence, upon the preparation of those elements of the Menomonee River watershed plan pertaining to water pollution control.

Water Resources Planning: Section 144.025(2)(a) requires that the Department of Natural Resources formulate a long-range comprehensive state water resources plan for each region in the State. The seven-county Southeastern Wisconsin Planning Region coincides with one of the water resources districts established by the Department. This section of the statutes also provides that the Department formulate plans and programs for the prevention and abatement of water pollution and for the maintenance and improvement of water quality. In addition, Section 144.02 of the Wisconsin Statutes authorizes the Department to conduct drainage basin surveys. This statutory authority provides the basis for the Department of Natural Resources to conduct the continuing state water quality management planning process required by the Federal Water Pollution Control Act.

Water Use Objectives and Water Quality Standards: Also under Section 144.025(a)(b) of the Wisconsin Statutes is authority for the Wisconsin Department of Natural Resources to prepare and adopt water use objectives and supporting water quality standards to apply to all of the surface waters of the State. Such authority is essential if the State is to meet the requirements of the Federal Water Pollution Control Act that such objectives and standards be established for all navigable waters in the United States. Such water use objectives and supporting water quality standards were initially adopted for interstate waters in Wisconsin on June 1, 1967, and for intrastate waters on September 1, 1968. On October 1, 1973, the Wisconsin Natural Resources Board adopted revised water use objectives and supporting water quality standards which are set forth in Chapters NR 102, NR 103, and NR 104 of the Wisconsin Administrative Code. The new objectives and standards are generally more stringent than the old, both with respect to the water use objectives established for the streams and lakes in the Southeastern Wisconsin Region and with respect to the supporting water quality standards.

Revised water quality standards have been formulated for the following major water uses: restricted use, public water supply, maintenance of a trout fishery, maintenance of salmon spawning, maintenance of a warm water fishery, and recreational use. The seventh water use relates to aesthetic considerations and provides minimum standards for all waters. The revised state standards are set forth in Table 96. These standards are statements of the physical, chemical, and biological characteristics of the water that must be maintained if the water is to be suitable for the specified uses.

Minimum Standards for All Waters: The revised state minimum standards apply to all surface waters at all locations within the State. These minimum standards are intended to protect the public health, to maintain all state waters in an aesthetically acceptable condition, and to protect domestic animals as well as wildlife.

Restricted Use: As indicated in Table 96, the restricted use category is intended to result in water quality a level above minimum standards. The most significant characteristics of the restricted use category are the inclusion of a requirement for minimum dissolved oxygen concentration and an upper limit on fecal coliform bacteria.

Public Water Supply: The principal criterion of quality standards in raw water intended to be used for public water supply is that the water, after appropriate treatment, be able to meet Wisconsin Department of Natural Resources drinking water standards established in 1974. The DNR standards of raw water to be used for water supply include an allowable pH range and maximum limits on temperature, dissolved solids, and fecal coliform.

Fish and Aquatic Life: Standards for water to be used for the preservation and enhancement of fish and aquatic life generally are specified in terms of parameters that affect the physiologic condition of the fish, the food chain that sustains the fish, and the aquatic environment. The DNR standards for fish and aquatic life, including the special subcategories of salmon spawning and trout fishery, are set forth in Table 96, and it is apparent that key factors include temperature, dissolved oxygen, and pH, in addition to other substances that may be harmful to the aquatic ecosystem. The adopted standards for the preservation and enhancement of fish and aquatic life include Lake Michigan thermal discharge standards which apply only to those facilities discharging heated water directly to Lake Michigan. The standards exclude municipal water and sewage treatment plants, as well as vessels or ships.

Recreation: Waters to be used for recreational purposes should be aesthetically attractive, free of substances that are toxic upon ingestion or irritating to the skin upon contact, and void of pathogenic organisms. The first two conditions are satisfied if the water meets the minimum standards for all waters as previously described, whereas the third condition requires that a standard be set to ensure safety of a water from the standpoint of health. The concentration of fecal coliform bacteria is the parameter now used for this purpose. Since the fecal coliform count is only an indicator of a potential public health hazard, the Wisconsin Standards, as set forth in Table 96, specify that a thorough sanitary survey to assure protection from fecal contamination be the chief criterion for determining recreational suitability.

Application of the Water Use Objectives to the Menomonee River Watershed: The application of the aforementioned six basic categories of water use objectives required specification of a design low flow at or above which the water quality standards commensurate with each water use objective are to be met. The water use objectives state that compliance with the supporting standards is to be evaluated on the basis of stream flow as low as the 7 day-10 year low flow, which is defined as the minimum 7-day mean low flow expected to occur once on the average of every 10 years. That is, for a given water use objective, the stream water quality is to be such as to satisfy the supporting standards for all stream flow conditions at or above the 7 day-10 year low flow.

The water use objectives established by the Wisconsin Department of Natural Resources for the surface of the Menomonee River watershed are identified on Map 82. The restricted use category is quite evident in the Menomonee River watershed, having been applied to Honey Creek and the South Branch of Underwood Creek in their entirety; Underwood Creek in Elm Grove, Wauwatosa, and West Allis; and the main stem of the Menomonee River downstream from its confluence with Honey Creek. The category applies to streams flowing through areas that are basically aesthetically unattractive and that actually inhibit access to the streams and potential users because of the nature and concentration of riverine development. The remaining surface waters of the Menomonee River watershed have been designated for recreational and fish and aquatic life uses.

Water Pollution Abatement Orders: Pursuant to Section 144.025(2)(c), the Department of Natural Resources is given authority to issue general orders applicable throughout the State to the construction, installation, use, and operation of systems, methods, and means for preventing and abating water pollution. This section also provides that the Department may adopt specific rules relating to the installation of water pollution abatement systems. Pursuant to this authority, the Department has adopted requirements for sewage disposal in Chapter NR 108 of the Wisconsin Administrative Code and for the design and operation of sewerage systems in Chapter NR 110 of the Wisconsin Administrative Code.

Special pollution abatement orders directing particular polluters to secure appropriate operating results at sewage treatment facilities in order to control water pollution or to cease the discharge of pollutants at a particular point are authorized to be issued by the Department in Section 144.025(2)(d). Such orders may prescribe a specified time for compliance with provisions of the order. Such orders are directed not only at municipal units of government that operate sewage treatment plants but also at private corporations and individuals who in any way discharge wastes to the surface or ground waters of the State. The Department has the power to make such investigations and inspections as are necessary to ensure compliance with any pollution abatement orders which it issues. In cases of noncompliance with any pollution abatement order, the Department has the authority to take any action directed by the order and to collect the costs thereof from the owner to whom the order was directed. Such charges become a lien against the property involved. To a large extent, the issuance of waste discharge permits as discussed below has become a substitute for the issuance of water pollution abatement orders by the Department, since such permits contain specified performance and operating standards.

Effluent Reporting and Monitoring System: Section 144.54 of the Wisconsin Statutes directs the Department of Natural Resources to require by rule that persons discharging industrial wastes, toxic and hazardous substances, or air contaminants submit a report on such discharges to the Department. The law further specifi-

Table 96

WISCONSIN DEPARTMENT OF NATURAL RESOURCES WATER USE OBJECTIVES AND SUPPORTING WATER QUALITY STANDARDS FOR SURFACE WATERS: 1973

Water Quality Parameters	Water Use Objectives[a,b,c,d]						Combinations of Water Use Objectives Applicable to Southeastern Wisconsin Inland Lakes and Streams[a]		
	Restricted Use	Recreational Use	Public Water Supply	Fish and Aquatic Life: Fishery	Fish and Aquatic Life: Salmon Spawning	Fish and Aquatic Life: Trout Fishery	Recreational Use and Fish and Aquatic Life	Recreational Use and Salmon Spawning	Recreational Use and Trout Fishery
Temperature (°F)	--[e]	--[e]	--[e]	--[e,f]	--[e]	--[e,g]	--[e,g]	--[e]	--[e,g]
Total Dissolved Solids (mg/l)	--	--	500 and[h] 750	--	--	--	--	--	--
Dissolved Oxygen (mg/l)	2.0_{min}	--	--	5.0_{min}	5.0_{min}[i]	6.0_{min}[j]	5.0_{min}	5.0_{min}[i]	6.0_{min}[j]
pH (Units)	6.0-9.0[k]	--	6.0-9.0[k]	6.0-9.0[k]	6.0-9.0[k]	6.0-9.0[k]	6.0-9.0[k]	6.0-9.0[k]	6.0-9.0[k]
Fecal Coliforms (MFFCC/100 ml)	1,000 and 2,000[l]	200 and 400[m]	200 and 400[m]	--	--	--	200 and 400[m]	200 and 400[m]	200 and 400[m]
Miscellaneous Parameters[n]	--[o]	--[o,p]	--[o,q]	--[o]	--[o]	--[o,r]	--[o,p]	--[o,p]	--[o,p,r]

Table 96 (continued)

[a] *Includes all basic water use categories established by the Wisconsin Department of Natural Resources plus those combinations of water use categories applicable to the Southeastern Wisconsin Region.*

[b] *Standards are expressed in mg/l except as indicated. Single numbers are maximum permissible values, except where minimum limits are denoted by the subscript Min.*

[c] *All waters shall meet the following conditions at all times and under all flow conditions: Substances that will cause objectionable deposits on the shore or in the bed of a body of water, shall not be present in such amounts as to interfere with public rights in waters of the state. Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in the waters of the state. Materials producing color, odor, taste, or unsightliness shall not be present in amounts found to be of public health significance, nor shall substances be present in amounts which are acutely harmful to animal, plant, or aquatic life.*

[d] *Water quality standards have not been formulated for commercial shipping and navigation since suitability for these uses depends primarily on quantity, depth, and elevation.*

[e] *There shall be no temperature changes that may adversely affect aquatic life. Natural daily and seasonal temperature fluctuations shall be maintained. The maximum temperature rise at the edge of the mixing zone above the existing natural temperature shall not exceed 5°F for streams and 3°F for lakes.*

[f] *The temperature shall not exceed 89°F for warm water fish.*

[g] *There shall be no significant artificial increases in temperature where natural trout reproduction is to be protected.*

[h] *Not to exceed 500 mg/l as a monthly average nor 750 mg/l at any time.*

[i] *The dissolved oxygen in the Great Lakes tributaries used by stocked salmonids for spawning runs shall not be lowered below natural background during the period of habitation.*

[j] *Dissolved oxygen shall not be lowered to less than 7.0 mg/l during the spawning season.*

[k] *The pH shall be within the range of 6.0 to 9.0 with no change greater than 0.5 units outside the estimated natural seasonal maximum and minimum.*

[l] *Shall not exceed a monthly geometric mean of 1,000 per 100 ml based on not less than five samples per month nor a monthly geometric mean of 2,000 per 100 ml in more than 10 percent of all samples during any month.*

[m] *Shall not exceed a monthly geometric mean of 200 per 100 ml based on not less than five samples per month nor a monthly geometric mean of 400 per 100 ml in more than 10 percent of all samples during any month.*

[n] *Lake Michigan thermal discharge standards, which are intended to minimize the effects on aquatic biota, apply to facilities discharging heated water directly to Lake Michigan, excluding that from municipal waste and water treatment plants and vessels or ships. Such discharges shall not raise the temperature of Lake Michigan at the boundary of the mixing zone established by the Wisconsin Department of Natural Resources by more than 3°F and, except for the Milwaukee and Port Washington Harbors, thermal discharges shall not increase the temperature of Lake Michigan at the boundary of the established mixing zones during the following months above the following limits:*

January, February, March	*45°F*
April	*55°F*
May	*60°F*
June	*70°F*
July, August, September	*80°F*
October	*65°F*
November	*60°F*
December	*50°F*

All owners utilizing, maintaining, or presently constructing thermal discharge sources exceeding a daily average of 500 million BTU per hour shall submit monthly temperature and flow data on forms prescribed by the Department of Natural Resources and shall, on or before February 1, 1974, submit to the Department a report on the environmental and ecological impact of such thermal discharges in a manner approved by the Department. After a review of the ecological and environmental impact of the discharge, mixing zones shall be established by the Department. New thermal discharge facilities (construction commenced after February 1, 1972 and prior to August 1, 1974) shall be so designed as to avoid significant thermal discharges to Lake Michigan. Any plant or facility, the construction of which is commenced on or after August 1, 1974, shall be so designed that the thermal discharges therefrom to Lake Michigan comply with mixing zones established by the Department. In establishing a mixing zone, the Department will consider ecological and environmental information obtained from studies conducted pursuant to February 1, 1974 and any requirements of the Federal Water Pollution Control Act Amendments of 1972.

[o] *Unauthorized concentrations of substances are not permitted that alone or in combination of, with other materials present, are toxic to fish or other aquatic life. Questions concerning the permissible levels, or changes in the same, of a substance, or combination of substances, of undefined toxicity to fish and other biota shall be resolved in accordance with the methods specified in "Water Quality Criteria," report of the National Technical Advisory Committee to the Secretary of the Interior, April 1, 1968. The committee's recommendations will also be used as guidelines in other aspects where recommendations may be applicable.*

[p] *A sanitary survey and/or evaluation to assure protection from fecal contamination is the chief criterion in determining the suitability of a surface water for recreational use.*

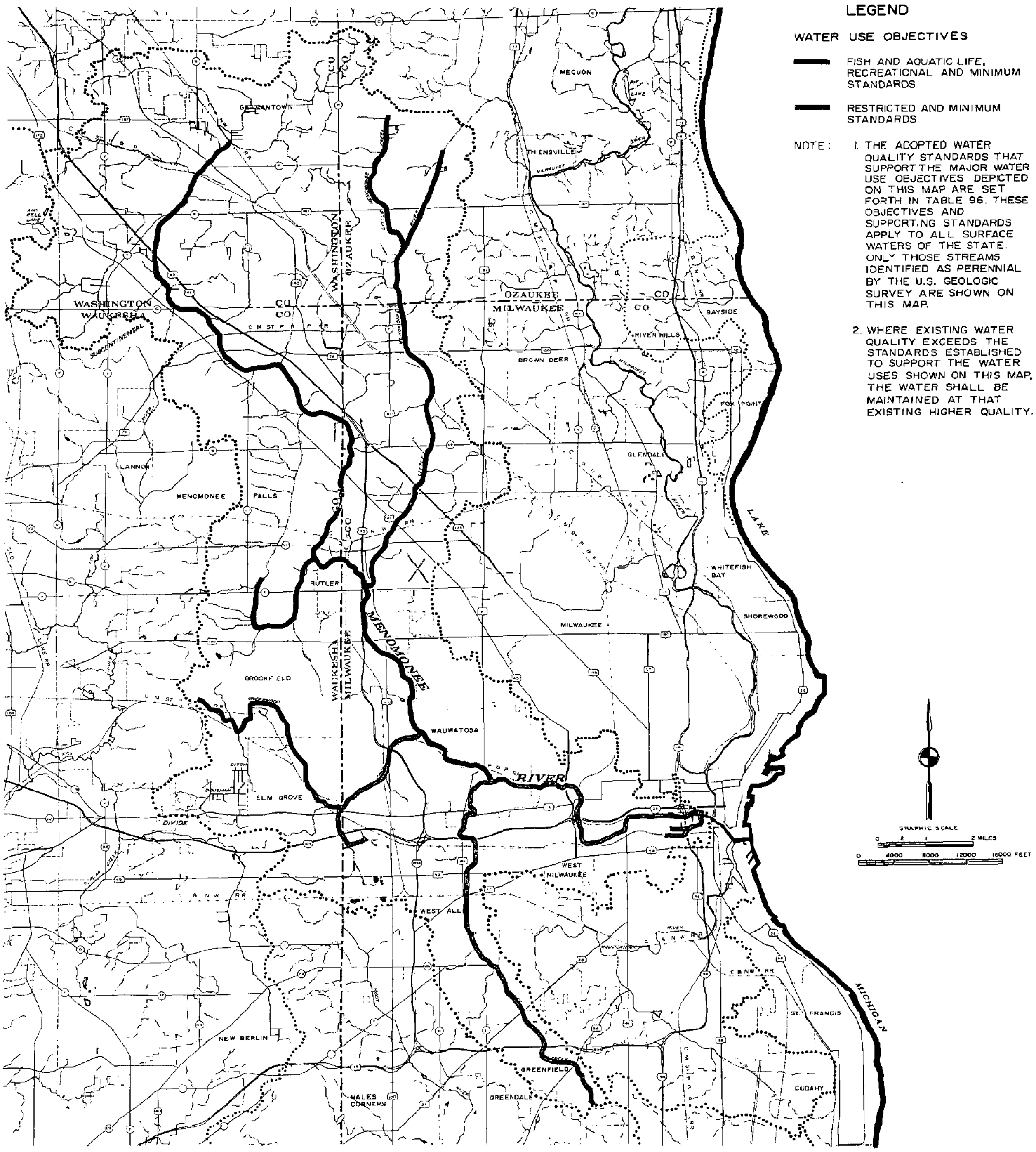
[q] *The intake water supply shall be such that by appropriate treatment and adequate safeguards it will meet the Public Health Service Drinking Water Standards established in 1962.*

[r] *Streams classified as trout waters by the DNR (Wisconsin Trout Streams, publication 213-72) shall not be altered from natural background by effluents that influence the stream environment to such an extent that trout populations are adversely affected.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 82

WISCONSIN DEPARTMENT OF NATURAL RESOURCES WATER USE OBJECTIVES FOR SURFACE WATERS IN THE MENOMONEE RIVER WATERSHED: 1973



Revised water use objectives for all surface waters in the Region, as well as for Lake Michigan, were adopted by the Wisconsin Natural Resources Board effective October 1, 1973. In the Menomonee River watershed most of the surface waters are designated for a combination of recreational and fishery uses under these recently adopted objectives. The exceptions are Underwood Creek downstream of Juneau Boulevard in the Village of Elm Grove, Honey Creek, the South Branch of Underwood Creek, and the main stem of the Menomonee River downstream of its confluence with Honey Creek. These stream reaches are designated "restricted," indicating that these waters need not support recreational and fishery uses.

Source: Wisconsin Department of Natural Resources and SEWRPC.

cally exempts municipalities from the rules and establishes an annual monitoring fee to provide for the cost of administering the program. In response to this statutory mandate, the Department prepared and adopted Chapter NR 101 of the Wisconsin Administrative Code setting forth specific rules by which the reporting and monitoring program is to be conducted. Of particular importance to water quality management are the effluent reports required in this chapter.

The rules require that every person discharging industrial wastes or toxic and hazardous substances is required to file an effluent report with the Department if 1) treated or untreated effluent is discharged directly to surface waters; 2) a minimum of 10,000 gallons of effluent per day, one or more days a year, is discharged to a land disposal system or to a municipal sewerage system; 3) less than 10,000 gallons per day is discharged to a land disposal system or a municipal sewerage system if the Department finds that reporting is necessary to protect the environment; and 4) more than 1,000,000 British thermal units are contributed per day, one or more days per year, to the effluent discharged to surface waters. Certain discharges are exempted from reporting, primarily if the discharge contributes none of the particular industrial wastes or toxic and hazardous substances specified in the Code. In addition, agricultural land runoff from land used exclusively for crop production need not be reported. Generally, the reports required by the Department must provide specific locations where effluent is being discharged to either surface waters, a sanitary sewerage system, or a land disposal system; estimates of the annual and average daily quantity of effluent discharged; concentrations and quantities of industrial wastes or toxic and hazardous substances contributed to the effluent in excess of the required reporting level; temperatures and volumes of thermal discharges; pH range of effluent; and a brief description of the manner and amount of raw materials used to produce wastes being reported.

Pollutant Discharge Permit System: Section 147.02 of the Wisconsin Statutes requires a permit for the legal discharge of any pollutant into the waters of the State, including groundwaters. This state pollutant discharge permit system was established by the Wisconsin Legislature in direct response to the requirements of the Federal Water Pollution Control Act of 1972, as discussed above. While the federal law envisioned requiring a permit only for the discharge of pollutants into navigable waters, in Wisconsin permits are required for discharges from point sources of pollution to all surface waters of the State and, additionally, to land areas where pollutants may percolate or seep to, or be leached to, groundwaters. Rules relating to the pollutant discharge elimination system are set forth in Chapter NR 200 of the Wisconsin Administrative Code.

Discharges for which permits are required include the following:

1. The direct discharge of any pollutant to any surface water.
2. The discharge of any pollutant, including cooling waters, to any surface water through any storm sewer system not discharging to publicly-owned treatment works.
3. The discharge of pollutants other than from agriculture for the purpose of disposal, treatment, or containment on land areas, including land disposal systems, such as ridge and furrow, irrigation, and ponding systems.

Certain discharges are exempt from the permit system, including discharges to publicly owned sewerage works; discharges from vessels; discharges from properly functioning marine engines; discharges of domestic sewage to septic tanks and drain fields, which are regulated under another section of the Wisconsin Administrative Code; the disposal of septic tank pumpage and other domestic waste, also regulated by another section of the Wisconsin Administrative Code; and the disposal of solid wastes, including wet or semiliquid wastes, when disposed of at a site licensed pursuant to another section of the Wisconsin Administrative Code.

The establishment of the Wisconsin pollution discharge permit system is a significant step both in terms of the data provided concerning point sources of pollution and in terms of the regulatory aspects of the permit system, including a listing of the treatment requirements and a schedule of compliance setting forth dates by which various stages of the requirements imposed by the permit shall be achieved. It is envisioned that the water quality management plans prepared pursuant to the terms of the Federal Water Pollution Control Act will be fully reflected in the permits issued under the pollutant discharge elimination system. As such, the pollutant discharge permit system becomes the primary vehicle for implementation of the basic goal of the Federal Water Pollution Control Act; namely, that of achieving the water use objectives for the receiving waters.

Septic Tank Regulation: In performing its functions of the maintenance and promotion of public health, the Wisconsin Division of Health is charged with the responsibility for regulating installation of private septic tank sewage disposal systems. Such systems often contribute to the pollution of surface and ground waters. Pursuant to Chapter 236 of the Wisconsin Statutes, the Division of Health reviews plats of all land subdivisions not served by public sanitary sewerage systems and may object to such plats if sanitary waste disposal facilities are not properly provided for in the layout of the plat. The Division has promulgated regulations governing lot size and elevation in Chapter H-65 of the Wisconsin Administrative Code. Basic regulations governing the installation of septic tank systems are set forth in Chapter H-62 of the Wisconsin Administrative Code. The Wisconsin Department of Natural Resources, however, must approve the provisions of the state plumbing code which sets specifications for septic tank systems and their installation. That Department also may prohibit the installation or use of septic tanks in any area of the State where the Department finds that the use of septic tanks would impair water quality. All septic tanks in the State must be registered by permit pursuant to Section 144.03 of the Wisconsin Statutes.

State Environmental Policy Act: The Wisconsin Legislature in April 1972 created Section 1.11 of the Wisconsin Statutes relating to governmental consideration of environmental impact. In many ways the state legislation parallels the National Environmental Policy Act of 1969 discussed earlier in this chapter. Under this state legislation, all agencies of the State must include a detailed environmental impact statement in every recommendation or report on proposals for legislation or other major actions which would significantly affect the quality of the human environment. The contents of this statement parallel the contents required in the federal environmental impact statements. The effect of the state legislation is, therefore, to extend the environmental impact statement concept to all state action not already covered under the federal legislation.

Local Water Quality Management

All towns, villages, and cities in Wisconsin have, as part of the broad grant of authority by which they exist, sufficient police power to regulate by ordinance any condition or set of circumstances bearing upon the health, safety, and welfare of the community. Presumably, the water quality of a receiving stream or the polluting capability of effluent generated within the municipal unit would fall within the regulative sphere by virtue of its potential danger to health and welfare. Such local ordinances could not, however, conflict with the federal and state legislation in this area.

Local and county boards of health have powers to adopt and enforce rules and regulations designed to improve the public health. This broad grant of authority includes regulatory controls relating to environmental sanitation and, hence, water pollution. County boards of health, established by action of the county board of supervisors pursuant to Section 140.09 of the Wisconsin Statutes, can provide an effective vehicle for the enactment of countywide regulations designed in part to prevent and control further pollution of surface and ground waters.

County park commissions established pursuant to Section 27.02 of the Wisconsin Statutes have powers to investigate the pollution of streams and lakes throughout the entire county and to engage in weed control and treatment practices in order to ameliorate one effect of such pollution: weed growth. In so doing, county park commissions may cooperate and contract with other counties and municipalities to provide for pollution control and lake and stream treatment.

Special Units of Government: In addition to the broad grant of authority to general purpose units of local government, the Wisconsin Statutes currently provide for the creation of five types of special purpose units of government through which water pollution can be abated and water quality protected. These are: 1) Metropolitan Sewerage District of the County of Milwaukee; 2) other metropolitan sewerage districts; 3) utility districts; 4) joint sewerage systems; and 5) cooperative action by contract.

Metropolitan Sewerage District of the County of Milwaukee: The Metropolitan Sewerage District of the County of Milwaukee was established and operates under the provisions of Section 59.96 of the Wisconsin Statutes. It operates through the agency of the Sewerage Commission of the City of Milwaukee, which was established pursuant to Chapter 608, Laws of Wisconsin 1913, and the Metropolitan Sewerage Commission of the County of Milwaukee, which operates and exists pursuant to the provisions of Section 59.96 of the Wisconsin Statutes. The Metropolitan Sewerage Commission has the power to project, plan, and construct main sewers as well as pumping and temporary disposal works for the collection and transmission of house, industrial, and other sanitary sewage to and into the intercepting sewerage systems of such District and it may improve any watercourse within the District by deepening, widening, or otherwise changing the same where, in the judgment of the Commission, it may be necessary to carry off surface or drainage waters. The Metropolitan Sewerage Commission may only exercise its powers outside of the City of Milwaukee. The Sewerage Commission of the City of Milwaukee, on the other hand, may build treatment plants and main and intercepting sewers and may improve watercourses within its area of operation, which is within the City of Milwaukee.

In order to coordinate the activities of the two Commissions, the Statutes provide that the Metropolitan Sewerage Commission must secure the approval of the Sewerage Commission of the City of Milwaukee before it is empowered to engage in any work and, when it has completed the work it proposes to do, then must turn over all of the facilities to the Sewerage Commission of the City of Milwaukee for operation and maintenance. Rules and regulations adopted by the Sewerage Commissions pursuant to the Statutes further provide for the coordination of the sewer improvement programs in the District by requiring that all cities and villages lying within the District and in contract service areas adjacent to the District must submit their sewerage system and construction plans for approval before they can connect to the main and intercepting system owned by the District. The two Commissions have the power to promulgate and enforce reasonable rules for the supervision, protection, management, and use of the entire sewerage system.

The District at the present time includes all of the cities and villages within the County of Milwaukee, except for the City of South Milwaukee, which elected not to become part of the District. In addition, the District, through its two Commissions, may enter into contracts with areas in the same general drainage area and adjacent to the District to furnish sewer service to those municipalities. The two Commissions have the power to inspect all sewers and sewerage systems which drain into the main or intercepting system and further have the power to require any town, city, or village or the occupant of any premises engaged in discharging sewage effluent from sewage plants, sewage refuse, factory wastes, or other materials into any river or canal within such County and within the drainage area so to change or rebuild any such outlet, drain, or sewer as to discharge said sewage waste or trade waste into the sewers of said town, city, or village or into the main intercepting sewers owned by the District.

With regard to watercourse improvements, the District, through its two Commissions, has engaged in a broad program of improving watercourses by widening, deepening, or otherwise changing said watercourses so as to accommodate the expected flow of storm and surface drainage waters from the area within the District and from the areas surrounding the District. In connection with this work, many unauthorized waste discharges to watercourses were uncovered and eliminated, thus reducing the discharge of objectionable materials into the rivers and streams in Milwaukee County, as well as providing greater capacity for such streams and rivers and providing for more rapid and efficient runoff of storm and drain waters.

The term "same general drainage area" referred to above, has been defined by the two Commissions to include all of the Kinnickinnic, Menomonee, and Milwaukee Rivers and Oak Creek watersheds and those portions of the Root River watershed draining into Milwaukee County. At the present time, jurisdiction of the joint Commissions in the Menomonee River watershed extends to all that portion of the watershed in Ozaukee, Milwaukee, and Waukesha Counties. In addition, the Commission has agreed to contract for future sewer service with the Village of Germantown in Washington County. For all practical purposes, then, the Metropolitan Sewerage District represents the single entity responsible for the conveyance and treatment of sanitary sewage in the Menomonee River watershed.

Other Metropolitan Sewerage Districts: In 1972 the Wisconsin Legislature enacted into law new enabling legislation for the creation of metropolitan sewerage districts outside of Milwaukee County. This legislation is set forth in Section 66.20 to 66.26 of the Wisconsin Statutes. This legislation provides that proceedings to create a metropolitan sewerage district may be initiated by resolution of the governmental body of any municipality. Such resolution, which must set forth a description of the territory proposed to be included in the district and a description of the functions proposed to be performed by the district, is directed at the Wisconsin Department of Natural Resources. Upon receipt of the resolution, the Department is required to schedule a public hearing for the purpose of permitting any persons to present any information relating to the matter of the proposed metropolitan sewerage district. Within 90 days of the hearing, the Department must either order or deny the formation of the proposed district. The Department must order the formation of the district if it finds that the district consists of at least one municipality in its entirety and all or part of other municipalities; if the district is determined to be conducive to management of a unified system of sewage collection and treatment; if the formation of the district will promote sound sewerage management policies and operation and is consistent with adopted plans of municipal, regional, and state agencies; and if the formation of the district will promote the public health and welfare and effect efficiency and economy in sewerage management. No territory of a city or village jointly or separately owning or operating a sewage collection or disposal system may be included in the district, however, unless it has filed with the Department of Natural Resources a certified copy of a resolution of its governing body consenting to the inclusion of its territory within the proposed district.

While metropolitan sewerage districts outside of Milwaukee County have importance in the Southeastern Wisconsin Region in other watersheds, they would have no practical importance in the Menomonee River watershed because of the existing and proposed contract authority of the Metropolitan Sewerage District of the County of Milwaukee. Accordingly, from a practical point of view, such districts are not of significance to the implementation of either the regional sanitary sewerage system plan in the Menomonee River watershed or to the Menomonee River watershed plan itself.

Utility Districts: Section 66.072 of the Wisconsin Statutes permits towns, villages, and cities of the third and fourth class to establish utility districts for a number of municipal improvement functions, including the provision of sanitary sewer service. Funds for the provision of services within the district are provided by levying a tax upon all property within the district. The establishment of utility districts requires a majority vote in towns and a three-fourths vote in cities and villages. Prior to establishing such a district, the local governing bodies also are required to hold a formal public hearing.

Joint Sewerage Systems: Section 144.07 of the Wisconsin Statutes provides the authority for a group of governmental units, including city, village, and town sanitary or utility districts, to construct and operate a joint sewerage system following hearing and approval by the Wisconsin Department of Natural Resources. The Statute provides that when one governmental unit renders such service as sewage conveyance and treatment to another unit under this section, reasonable compensation is to be paid. Such reasonable charges are to be determined by the governmental unit furnishing the service. If the governmental unit receiving this service deems the charge unreasonable, the Statutes provide for either binding arbitration by a panel of three reputable and experienced engineers or for judicial review in the circuit court of the county of the governmental unit furnishing the service. In the alternative, the jointly acting governmental units may create a sewerage commission to project, plan, construct, and maintain in the area sewerage facilities for the collection, transmission, and treatment of sewage. Such a sewerage commission becomes a municipal corporation and has all the powers of a common council and board of public works in carrying out its duties. However, all bond issues and appropriations made by such a sewerage commission are subject to approval by the governing bodies of the units of government which initially formed the commission. The Statutes provide that each governmental unit must pay its proportionate share of constructing, operating, and maintaining the joint sewerage system. Grievances concerning same may be taken to the circuit court of the county in which the aggrieved governmental unit is located.

Cooperative Action by Contract: Section 66.30 of the Wisconsin Statutes permits the joint exercise by municipalities, broadly defined to include the State or any department or agency thereof or any city, village, town, county, school district, public library system, sanitary district, or regional planning commission, of any power or duty required of, or authorized to, such municipality by statute. To jointly exercise any such power, such as the transmission, treatment, and disposal of sanitary sewage, municipalities would have to create a commission by contract. Appendix A to SEWRPC Technical Report No. 6, Planning Law in Southeastern Wisconsin, contains a model agreement creating such a cooperative contract commission. Two such contract commissions have been created under this Statute in the Menomonee River watershed for water quality management purposes. The first of these is the Underwood Sewer Commission jointly created by contract between the City of Brookfield and the Village of Elm Grove. The purpose of this cooperative action was to provide for the construction, operation, and maintenance of a major trunk sewer along Underwood Creek which provides for conveyance for sewage from both communities to the Milwaukee-metropolitan sewerage system for sewage treatment purposes. The second is the Menomonee South Sewerage Commission jointly created by contract between the City of Brookfield and the Village of Menomonee Falls to provide for the construction, operation, and maintenance of a major trunk sewer along Butler Ditch.

Shoreland Regulation: The State Water Resources Act of 1965 provides for the regulation of shoreland uses along navigable waters to assist in water quality protection and pollution abatement and prevention. In Section 59.97(1) of the Wisconsin Statutes, the Legislature defines shorelands as all that area lying within the following distances from the normal high water elevation of all natural lakes and of all streams, ponds, sloughs, flowages, and other waters which are navigable under the laws of the State of Wisconsin: 1,000 feet from the shoreline of a lake, pond, flowage, or glacial pothole lake and 300 feet from the shoreline of a stream or to the landward side of the floodplain, whichever is greater.

Section 144.26 of the Wisconsin Statutes specifically authorizes municipal zoning regulations for shorelands. This Statute further defines municipality as meaning a county, city, or village. Furthermore, the shoreland regulations authorized by this Statute have been defined by the Wisconsin Department of Natural Resources to include land subdivision controls and sanitary regulations. The purposes of zoning, land subdivision, and sanitary regulations in shoreland areas include the maintenance of safe and healthful conditions in riverine areas; the prevention and control of water pollution; the protection of spawning grounds, fish, and aquatic life; the control of building sites, placement of structures, and land use; and the preservation of shore cover and natural beauty. A more complete discussion of local shoreland regulatory powers is contained in SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide.

Private Steps for Water Pollution Control

The foregoing discussion deals exclusively with water pollution control machinery available to units and agencies of government. Direct action may also be taken, however, by private individuals or organizations to effectively abate water pollution. In seeking direct action for water pollution control there are two legal categories of private individuals: riparians, or owners of land along a natural body of water, and nonriparians.

Riparians: It is not enough for a riparian proprietor seeking an injunction to show simply that an upper riparian is polluting the stream and thus he, the lower riparian, is being damaged. Courts will often inquire as to the nature and the extent of the defendant's activity; its worth to the community; its suitability to the area; and his present attempts, if any, to treat wastes. The utility of the defendant's activity is weighed against the extent of the plaintiff's damage within the framework of reasonable alternatives open to both. On the plaintiff's side, the court may inquire into the size and scope of his operations, the degree of water purity that he actually requires, and the extent of his actual damages. This approach may cause the court to conclude that the plaintiff is entitled to a judicial remedy. Whether this remedy will be an injunction or merely an award of damages depends on the balance which the court strikes after reviewing all the evidence. For example, where a municipal treatment plant or industry is involved, the court, recognizing equities on both sides, might not grant an injunction stopping the defendant's activity but might compensate the plaintiff in damages. In addition, the court may order the defendant to install certain equipment or to take certain measures designed to minimize the future polluting effects of his waste disposal. It is not correct to characterize this balancing as simply a test of economic strengths. If it were simply a weighing of dollars and cents, the rights of small riparians would never receive protection. The balance that is struck is one of reasonable action under the circumstances, and small riparians can be and have been adequately protected by the courts.

Riparians along water bodies in the Southeastern Wisconsin Region are not prevented by the existence of federal, state, or local pollution control efforts from attempting to assert their common law rights in courts. The court may ask the Wisconsin Department of Natural Resources to act as its master in chancery, especially where unbiased technical evidence is necessary to determine the rights of litigants. The important point, however, is that nothing in the Wisconsin Statutes can be found which expressly states that, in an effort to control pollution, all administrative remedies must first be exhausted before an appeal to the courts may be had or that any derogation of common law judicial remedies was intended. Thus, the courts are not prevented from entertaining an original action brought by a riparian owner to abate pollution.

Nonriparians: The rights of nonriparians to take direct action through the courts are less well defined than in the case of riparians. The Wisconsin Supreme Court set forth a potentially far-reaching conclusion in Muench v. Public Service Commission[15] when it concluded that:

> The rights of the citizens of the state to enjoy our navigable streams for recreational purposes, including the enjoyment of scenic beauty, is a legal right that is entitled to all the protection which is given financial rights.

This language, however, was somewhat broader than necessary to meet the particular situation at hand, since the case involved an appeal from a state agency ruling. The case has not yet arisen where a private nonriparian citizen is directly suing to enforce his public rights in a stream. Only when such a case does arise can it be determined if the Court will stand behind the broad language quoted above or draw back from its implications. The more traditional view would be that a nonriparian citizen must show special damages in a suit to enforce his public rights.

It should be noted that Section 144.537 of the Wisconsin Statutes presently enables six or more citizens, whether riparian or not, to file a complaint leading to a full-scale public hearing by the Department of Natural Resources on alleged or potential acts of pollution. In addition, a review of Department orders may be had pursuant to Section 144.56 of the Wisconsin Statutes by "any owner or other person in interest." This review contemplates eventual court determination under Chapter 227 of the Wisconsin Statutes when necessary. The phrase "or other person" makes it clear that nonriparians may ask such judicial review.

The Federal Water Pollution Control Act also provides for citizen suits. Under this law, any citizen, meaning a person or persons having an interest which is or may be adversely affected, may commence a civil action on his own behalf against any person, including any governmental agency, alleged to be in violation of any effluent standard, limitation, or prohibition or any pollution discharge permit or condition thereof; or against the EPA Administrator when there is alleged failure by the Administrator to duly carry out any nondiscretionary duty or act under the Federal Water Pollution Control Act. Prior to bringing such action, however, the citizen commencing the action must give notice of the alleged violation to the EPA Administrator, to the state in which the alleged violation occurs, and to the alleged violator. The courts when issuing final orders in any action under this section may award costs of litigation to any party.

FLOODLAND REGULATION

Effective abatement of flooding can be achieved only by a comprehensive approach to the problem. Certainly, physical protection from flood hazards through the construction of dams, flood control reservoirs, levees, channel improvements, and other water control facilities is not to be completely abandoned in favor of floodland regulation. As urbanization proceeds within a watershed, however, it becomes increasingly necessary to develop an integrated program of land use regulation of the floodlands within the entire watershed to supplement required water control facilities if efforts to provide such facilities are not to be self-defeating.

Definition of Floodlands

The precise delineation of floodlands is essential to the sound, effective, and legal administration of floodland regulations. This is particularly true in urbanizing areas, such as the Menomonee River watershed. A precise definition of floodlands is not found in the Wisconsin Statutes. Section 87.30(1) speaks only of those areas within a stream valley within which "serious (flood) damage may occur" or "appreciable (flood) damage . . . is likely to occur." This statutory description is not adequate per se for floodland determination. As a watershed urbanizes, and the hydraulic characteristics of a stream are altered, additional areas of a stream valley become subject to flooding. It becomes necessary, therefore, to regulate the entire potential, as well as existing, floodland areas.

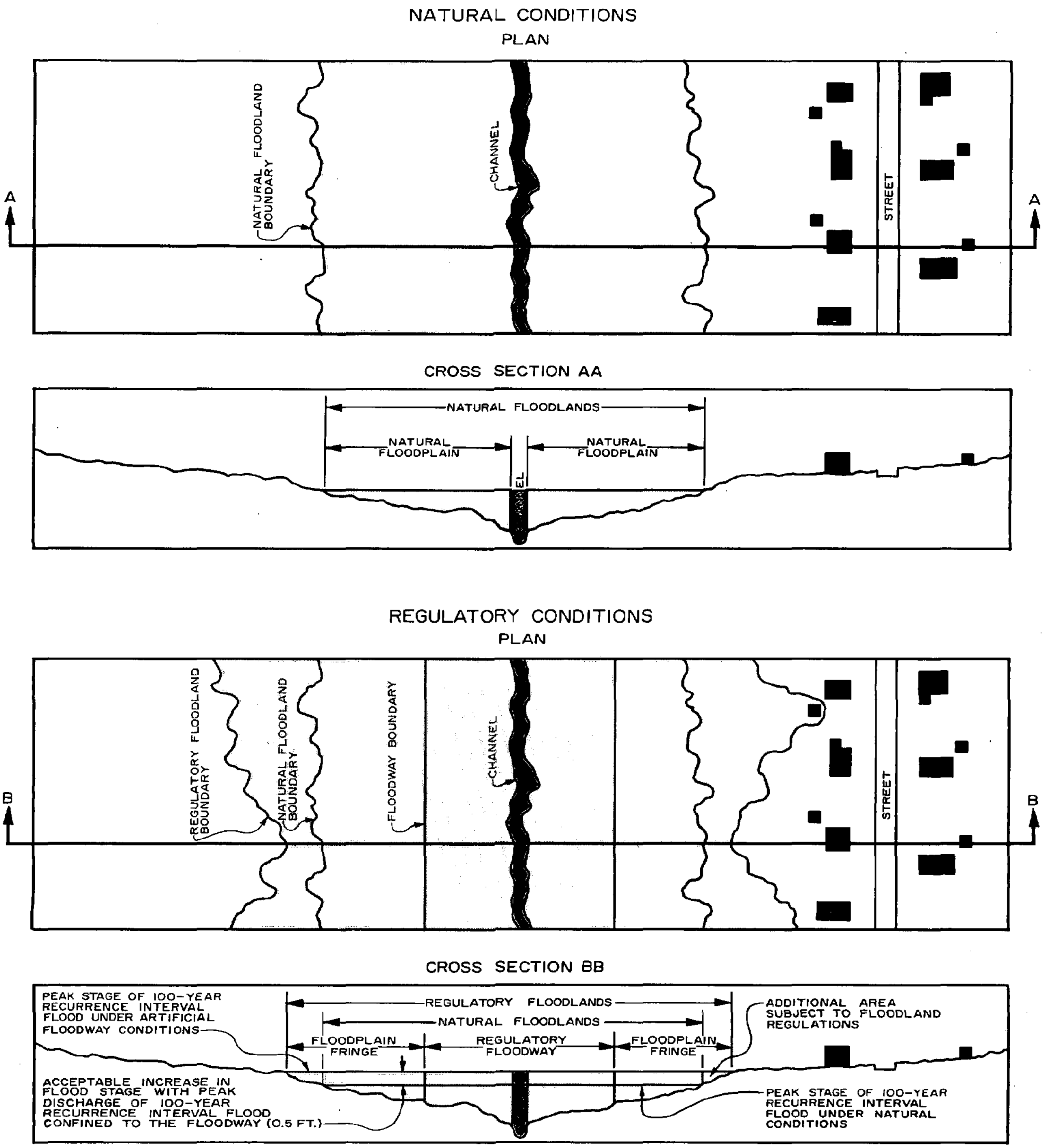
In planning for the proper use of floodlands, it is useful to subdivide the total floodland area on the basis of the hydraulic function which the various subareas are to perform, as well as on the basis of the differing degrees of flood hazard that may be present (see Figure 85). Under natural conditions, the floodlands may be considered as consisting of two components, the channel of the river, or stream itself, and the adjacent natural floodplains. The channel may be defined as the continuous linear area occupied by the river or stream in times of normal flow. The natural floodplain may be defined as the wide, flat-to-gently sloping area contiguous with and lying adjacent to the channel, usually on both sides. The floodplain is normally bounded on its outer edges by higher topography. A river may be expected to overflow its channel banks and occupy some portion of its floodplains on the average of once every two years. How much of the natural floodplain will be occupied by any given flood will depend upon the severity of that flood and, more particularly, upon its elevation or stage. Thus, an infinite number of outer limits of the natural floodplain may be delineated, each related to a corresponding specified flood recurrence interval. The Commission has, therefore, recommended that the natural floodplains of a river or stream be specifically defined as those being confined to a flood having a recurrence interval of 100 years; that is, a flood having a 1 percent chance of occurring in any given year. This definition corresponds to the regulatory flood selected for use by the Wisconsin Department of Natural Resources in administering Wisconsin's floodplain management program set forth in Chapter NR 116 of the Wisconsin Administrative Code.

Under ideal regulatory conditions, the entire natural floodlands as defined above would be maintained in an open, essentially natural state, and, therefore, would not

[15] *261 Wis. 492, 53 N.W. 2d 514 (1952).*

Figure 85

FLOODLAND COMPONENTS UNDER NATURAL AND REGULATORY CONDITIONS



Source: SEWRPC.

be filled and utilized for incompatible, intensive urban land uses. Conditions permitting an ideal approach to floodland regulation, however, generally occur only in rural areas. In areas which have already been developed for intensive urban use without proper recognition of the flood hazard, a practical regulatory approach must embrace the concept of a floodway. The floodway may *be defined as a designated portion of the floodlands* that will safely convey the 100-year recurrence interval flood discharge, with small upstream and downstream stage increases allowed, generally limited in Wisconsin to 0.5 foot if the stage increase does not increase the flood damage potential. The regulatory floodway includes the channel. Land use controls applied to the regulatory floodway should recognize that the designated floodway area is not suited for human habitation and should essentially prohibit all fill, structures, and other development that would impair flood water conveyance by adversely increasing flood stages or velocities.

The floodplain fringe is that remaining portion of the floodlands lying outside of or beyond the floodway. Because the use of a regulatory floodway may result in increases in the stage of a flood of a specified occurrence interval that would not occur under natural conditions, the floodplain fringe may include at its very edges areas that would not be subject to inundation under natural conditions, but which would be subject to inundation under regulatory floodway conditions and, therefore, come within the scope of necessary floodplain fringe regulation. Normally, flood water depths and velocities are low in the floodplain fringe and, accordingly, filling and urban development may be permitted although regulated to minimize flood damages. Under "real world" conditions, the floodplain fringe usually includes many existing buildings constructed in natural floodlands prior to the advent of sound floodland regulation.

The delineation of the limits of the floodland regulatory area should be based upon careful hydrologic and hydraulic studies, such as have been conducted under the Menomonee River watershed study for the Menomonee River and its major tributaries.

Principles of Floodland Regulation

Certain legal principles must be recognized in the development of land use regulations that would be designed to implement a comprehensive watershed plan. With respect to the floodland areas of the watershed, these are as follows:

1. Sound floodland regulation must recognize that the flood hazard is not uniform over the entire floodland area. Restrictions and prohibitions in floodlands should, in general, be more rigorous in the channel itself and in the floodway than in the floodplain fringe area.

2. While it is most desirable that floodland regulations seek to retain floodlands in open space uses, sound floodland regulation may contemplate permitting certain buildings and structures at appropriate locations in the floodplain fringe. Any such structure, however, should comply with special design, anchorage, and building material requirements.

3. Sound floodland regulation must recognize, and be adjusted to, existing land uses in the floodlands. Structures already may exist in the wrong places. Fills may be in place constricting flood flows or limiting the flood storage capacities of the river. The physical effects of such misplaced structures and materials on flood flows, stage, and velocities, can be determined; and floodland regulation based on such determinations must include legal measures to bring about the removal of at least the most troublesome of offenders.

4. In addition to the physical effects of structures and materials, sound floodland regulation also must be concerned with the social and economic effects, particularly the promotion of public health and safety. Beyond this, sound floodland regulation must take into account such diverse and general welfare items as impact upon property values, the property tax base, human anguish, aesthetics, and the need for open space.

5. Sound floodland regulation must coordinate all forms of land use controls, including zoning, subdivision control, and official map ordinances and housing, building, and sanitary codes.

Land Use Regulation in Floodlands

Based upon the above principles and upon the definition of floodlands set forth above, the Commission has proposed that the local units of government within the entire Region utilize a variety of land use controls to effect proper floodland development. The use of these controls is discussed in SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide, and, therefore, will not be repeated here. The following section, however, will summarize the various land use regulatory powers available to state, county, and local units of government for use in regulating floodland development.

Channel Regulation: Sections 30.11, 30.12, and 30.15 of the Wisconsin Statutes establish rules for the placement of material and structures on the bed of any navigable water and for the removal of material and structures illegally placed on such beds. With the approval of the Wisconsin Department of Natural Resources, pursuant to Section 30.11 of the Wisconsin Statutes, any town, village, city, or county may establish bulkhead lines along any section of the shore of any navigable water within its boundaries. Where a bulkhead line has been properly established, material may be deposited and structures built out to the bulkhead line, consistent with the appropriate floodway zoning ordinance. A Wisconsin Department of Natural Resources permit is required for deposit of material or erection of a structure beyond the bulkhead line. Where no bulkhead line has been established, it is unlawful to deposit any material or build any structure upon the bed of any navigable water unless a Wisconsin Department of Natural Resources permit has first been obtained.

The delineation of the outer boundary of the bed of a navigable lake or stream thus becomes a crucial legal issue, and the Statutes provide no assistance in this problem. Where the lake or stream has sharp and pronounced banks, it will ordinarily be possible, using stage records, the testimony of knowledgeable persons, and evidence relating to types of vegetation and physical characteristics of the bank, to establish the outer limits of the stream or lake bed. The task can present a difficult practical problem, however, particularly where the stream is bordered by low-lying wetlands. Where bulkhead lines have been established, however, or where the outer limits of navigable waters can be defined, existing encroachments in the beds of these navigable waters can be removed and new encroachments prevented under existing Wisconsin Legislation.

Floodway and Floodplain Fringe Regulation: The regulation of floodlands in Wisconsin is governed primarily by the rules and regulations adopted by the Wisconsin Department of Natural Resources pursuant to Section 87.30 of the Wisconsin Statutes. In addition, with the advent of the federal flood insurance program, the enactment of floodland regulations in Wisconsin is further governed by rules promulgated by the U. S. Department of Housing and Urban Development. In essence, floodland regulation in Wisconsin is a partnership between the local, state, and federal levels of government.

State Floodplain Management Program: While the Wisconsin Legislature long ago recognized that the regulation of stream channel encroachments was an areawide problem transcending county and municipal boundaries and, therefore, provided for state regulation, it was not until passage of the State Water Resources Act in August 1966 that a similar need was recognized for floodway and floodplain fringe regulation. In that Act, the Legislature created Section 87.30 of the Wisconsin Statutes. This section authorizes and directs the Wisconsin Department of Natural Resources to enact floodland zoning regulations where it finds that a county, city, or village has not adopted reasonable and effective floodland regulations. The cost of the necessary floodplain determination and ordinance promulgation and enforcement by the State must, under the Statute, be assessed and collected as taxes from the county, city, or village by the State. Chapter NR 116 of the Wisconsin Administrative Code sets forth the general criteria for counties, cities, and villages to follow in enacting reasonable and effective floodland regulations. In addition to providing for the proper administration of a sound floodland zoning ordinance, the criteria include that, where applicable, floodland zoning ordinances be supplemented with land subdivision regulations, building codes, and sanitary regulations.

In practice, the Department of Natural Resources issues orders to counties, cities, and villages when sound flood hazard data become available for use in floodland regulation. In the Southeastern Wisconsin Region, this has generally meant that such orders are issued to communities upon completion of comprehensive watershed studies developed by the Regional Planning Commission, which studies include the definitive determination of flood hazard areas. These orders normally provide a period of six months upon receipt of the flood hazard data for the enactment of the necessary local regulations.

State Agency Coordination: On November 26, 1973, Governor's Executive Order No. 67 was issued. It was designed to promote a unified state policy of comprehensive floodplain and shoreland management. The key provisions of the executive order are as follows:

1. All state agencies are now required to consider flooding and erosion dangers in the administration of grant, loan, mortgage insurance, and other financing programs.

2. All state agencies that are involved in land use planning are required to consider flooding and erosion hazards when preparing and evaluating plans. In addition, all state agencies directly responsible for new construction of state facilities, including buildings, roads, and other facilities, are required to evaluate existing and potential flood hazards associated with the construction activity.

3. All state agencies which are responsible for the review and approval of subdivision plats, buildings, structures, roads, and other facilities are required to evaluate existing or potential flood hazards in connection with the proposed development activity.

4. In its license review, suspension, and revocation procedures, the State Real Estate Examining Board must consider the failure of real estate brokers, salesmen, or agents to properly inform a potential purchaser that property under consideration lies within an area subject to flooding or erosion hazards.

The provisions of this executive order are extremely important in that all state agencies are now required to utilize the flood hazard data that have been and are being developed, and thus will assist in assuring that state-aided action, such as highway construction, will not contribute to increasing flooding and erosion hazards or changing the character of the flooding. The order also assures that state agency actions will be consistent with local floodland regulations.

Federal Flood Insurance Program: A program to enable property owners to purchase insurance to cover losses caused by floods was established by the U. S. Congress in the National Flood Insurance Act of 1968. Taking note that many years of installation of flood protection works had not reduced losses caused by flood damages, the Congress sought to develop a reasonable method of sharing the risk of flood losses through a program of flood insurance, while at the same time setting in motion local government land use control activity that would seek to ensure, on a nationwide basis, that future urban development within floodlands would be held to a minimum.

The Act created a national flood insurance program under the direction of the Secretary of the U. S. Department of Housing and Urban Development (HUD). The Secretary was given broad authority to conduct all types of studies relating to determination of floodlands and the risks involved in ensuring development that may be situated in natural floodland areas. The Act provided for the establishment of a national flood insurance fund, part of which would be established by congressional appropriations, designed to assist in subsidizing insurance rates where necessary to encourage the purchase of flood insurance by individual land owners and thus reduce the need for periodic federal disaster assistance. Congress made clear, however, that the establishment of such a program was not intended to encourage additional future development in flood-prone areas, but rather to assist in spreading the risks created by existing floodland development while at the same time taking effective action to ensure that local land use control measures effectively reduce future flood losses through prohibiting unwise floodland development.

Participation in the national flood insurance program is on a voluntary community-by-community basis. A community must act affirmatively to make its residents eligible to purchase flood insurance. Once a community makes it known to the Secretary of the U. S. Department of Housing and Urban Development that it wishes to participate in the program, the Secretary authorizes appropriate studies to be made to determine the special flood hazard areas that may exist within the community and the rates at which flood insurance may be made available. In the Southeastern Wisconsin Region, such flood insurance studies build upon and at times supplement the flood hazard data made available by the Regional Planning Commission under the comprehensive watershed planning programs. When the federal studies are completed, the Secretary publishes a flood hazard boundary map or maps, which identify the areas of "special flood hazard," and a flood insurance rate map or maps, which divide the community into various zones for insurance purposes. A landowner is then eligible to go to any private insurance agent and purchase flood insurance up to certain specified maximums at the rates established by the Secretary. Such rates can be federally subsidized if the actuarial rates would result in a likelihood of widespread nonparticipation in the program. For its part, the community must enact land use controls which meet federal standards for floodland protection and development. For all practical purposes, once a community enacts floodland regulations that meet the state requirements set forth in Chapter NR 116 of the Wisconsin Administrative Code, it will have been deemed to meet all federal requirements for similar controls.

In 1973 the U. S. Congress expanded the national flood insurance program through enactment of the Federal Flood Disaster Protection Act of 1973. In addition to increasing the amount of both subsidized and unsubsidized flood insurance coverage available for all types of properties, this Act expanded the insurance program to include erosion losses cuased by abnormally high water levels. In addition, the Act provides that the purchase of flood insurance is required for all structures within flood hazard areas when a purchaser seeks a mortgage through a federally supervised lending institution. And the Act requires that, as a condition of future federal disaster assistance in flood hazard areas, flood insurance must be purchased so as to ensure that the next time a property is damaged by floods, the losses will be covered by insurance and federal disaster assistance will not be needed.

CONSTRUCTION OF FLOOD CONTROL FACILITIES BY LOCAL UNITS OF GOVERNMENT

Sound physical planning principles dictate that a watershed be studied in its entirety if practical solutions are to be found to water-related problems, and that plans and plan implementation programs, including the construction of flood control facilities, be formulated to deal with the interrelated problems of the watershed as a whole. A watershed, however, typically is divided in a most haphazard fashion by a complex of man-made political boundaries—county, city, village, town, and special district. When public works projects such as flood control works, covering and serving an entire watershed, are required, these artificial demarcations become extremely important because they limit the jurisdiction—the physical area—within which any one particular arm of local government may act. Two general possibilities exist with respect to the Menomonee River watershed by which this limitation may be overcome. These two possibilities are: 1) cooperative action by contract and 2) the use of special districts.

Cooperative Action by Contract

The use of Section 66.30 of the Wisconsin Statutes to achieve cooperative contract action was previously discussed under the section on water quality management. The local units of government concerned with the construction of mutually advantageous flood control facilities could proceed under the provisions of Section 66.30 of the Wisconsin Statutes to implement specific water control facility plans under a contractual relationship. If it is assumed that the benefits of comprehensive watershed public works accrue in some rough proportion to all of the municipal units involved and that the self-interest and sense of propriety of each would impell them all to be a party to a contract, then the contractual provisions of Section 66.30 of the Wisconsin Statutes seem completely capable of dealing with the problem. A commission could be created to administer the contracts; or, seemingly, any other administrative device mutually agreed upon could be created to carry out the joint public works projects deemed necessary.

Use of Special Districts

Several types of special districts are available or potentially available for use in the construction and operation of flood control facilities. These special districts are: 1) Metropolitan Sewerage District of the County of

Milwaukee, 2) a comprehensive river basin district, 3) soil and water conservation districts, and 4) flood control boards.

Metropolitan Sewerage District of the County of Milwaukee: As noted earlier in this chapter under the discussion of local water quality management, the Metropolitan Sewerage District of the County of Milwaukee, operating through the agency of the Sewerage Commission of the City of Milwaukee and the Metropolitan Sewerage Commission of the County of Milwaukee, may improve watercourses through deepening, widening, or otherwise changing when in the judgment of the Commissions such improvements are necessary in order to carry off surface or drainage waters. The district, through its two Commissions, has historically engaged in a broad program of improving watercourses in the Menomonee River watershed by widening and deepening such watercourses so as to accommodate the expected flow of storm and surface drainage waters from the areas involved. In particular, as noted in Chapter V of this report, the District has improved the drainage characteristics of Honey Creek, Underwood Creek, and the main stem of the Menomonee River within the Menomonee River watershed.

Comprehensive River Basin District: One possibility for areawide water control facility plan implementation is through the creation of a special comprehensive river basin district embracing the entire watershed and capable of raising revenues through taxation and bonding; acquiring land; constructing and operating the necessary facilities; and otherwise dealing with a wide range of problems, alternatives, and projects inherent in comprehensive watershed planning. Such a district might be specifically charged in the enabling legislation by which it is created with carrying out the plans formulated by the SEWRPC. Though enabling legislation to permit the creation of such districts has been proposed to the Wisconsin Legislature in the past, it has not, to date, received approval and, thus, is not presently available as an alternative means of dealing with the problem.

Soil and Water Conservation Districts: Present legislation, Chapter 92 of the Wisconsin Statutes, authorizes the creation of soil and water conservation districts, the boundaries of which must be coterminous with county lines. There exists such a district in each county of the Menomonee River watershed. These districts, to date, have had a strong agricultural orientation; and in southeastern Wisconsin their efforts have been focused primarily on inducing individual farmers to use good soil management and conservation techniques. Respective county board agricultural and extension education committee members are ex officio members of the board of supervisors of the soil and water conservation district. In general these districts have conducted programs designed to encourage sound and proper land use and have been used by the Wisconsin Department of Natural Resources, the U. S. Soil Conservation Service, and the University of Wisconsin Extension as a vehicle for achieving good land use development objectives in rural areas. Of major practical significance is the fact that these districts have no taxing, special assessment, or bonding power but are completely dependent upon county funds and U. S. Department of Agriculture grants for financing. Federal grants under Public Law 83-566 can be obtained by such districts for the construction of flood control projects only if federal preconditions are met. If, however, any proposed flood control facilities within the Menomonee River watershed can meet these requirements, these districts may serve as an agent for federal financing of the project.

The Wisconsin Board of Soil and Water Conservation Districts which oversees the activities of the county soil and water conservation districts, performs an important role with respect to flood control. The Board must approve all local applications for federal grants for flood control projects under PL-83-566. In addition the Board must approve all work plans in the State of Wisconsin for projects under the PL-83-566 program and set the planning priorities for the U. S. Soil Conservation Service operation within the State.

Flood Control Boards: Chapter 87 of the Wisconsin Statutes makes provisions for property owners living in a single drainage area, which may well involve more than a single municipal governmental unit, to petition for the formation of a flood control board for the sole purpose of effecting flood control measures. These measures may include the

> . . . straightening, widening, deepening, altering, changing, or the removing of obstructions from the course of any river, watercourse, pond, lake, creek, or natural stream, ditch, drain, or sewer, and the concentration, diversion, or division of the flow of water therein, the construction and maintenance or the removal of ditches, canals, levees, dikes, dams, sloughs, revetments, reservoirs, holding basins, floodways, pumping stations, sewers and siphons, and any other works reasonably adapted or required to accomplish the purposes of (this chapter). . .[16]

Application for the creation of such a board must be made through the Department of Natural Resources, which determines the need and engineering feasiblity of the proposed projects. Boards created under this statutory chapter are empowered to raise monies by the levy of a special assessment against the benefited property owners. The board is also empowered to determine the benefits to be derived within each affected municipality. In addition, the Wisconsin Legislature recently provided a more flexible financing procedure whereby flood control projects may be financed in whole or in part through funds received under agreements and contracts from municipalities, other governmental agencies, and other sources. In providing money for such projects, municipalities may utilize the powers of special assessment, bonding, and taxation. The legislature also relatively recently

[16]*Wisconsin Statute 87.02.*

provided a special procedure whereby the Department of Natural Resources may order the creation of flood control boards.

DEVELOPMENT AND OPERATION OF HARBORS

The authority to develop and operate harbors and make harbor improvements is granted to every municipality in Wisconsin having navigable waters within or adjoining its boundaries by Sections 30.30 through 30.38 of the Wisconsin Statutes. Such authority may be exercised directly by the governing body of the municipality or by a board of harbor commissioners created for that purpose, except that certain enumerated powers relating to the commercial aspects of harbor operation, such as the operation of publicly owned or leased wharf and terminal facilities, can only be exercised through a board of harbor commissioners. Boards of harbor commissioners are fiscally dependent upon the governing body of the municipality.

Under the statutory authority, boards of harbor commissioners are authorized to establish or improve any inner or outer harbor turning basins, slips, canals, and other waterways; to construct, maintain, or repair dock walls and shore protection walls along any waterway adjoining or within the limits of the municipality; and to plan, construct, operate, and maintain docks, wharves, warehouses, piers, and related port facilities for the need of commerce and shipping, including the handling of freight and passenger traffic between the waterways of the harbor and air and land transportation terminals. Boards may acquire land, develop industrial sites, build service roads, and construct and enlarge harbor facilities. All plans for harbor improvement projects, including the establishment of dock lines, must be approved by the governing body of the municipality.

Boards of harbor commissioners also may serve as a regulatory and enforcement agency for the municipality with respect to such harbor-related matters as the movement of vessels, dock wall construction, and shoreline encroachment. In this respect it is important to note that boards of harbor commissioners, to promote the public health, safety, or welfare or to eliminate dilapidation, blight, or obsolescence, can determine by resolution that it is essential that dock walls or shore protection walls be improved, altered, repaired, or extended. Property owners affected by such resolution can appeal the finding and order of the board to make improvements to the courts. Should the court eventually order the work to be performed, the property owner may elect to do the work or let the municipality do the work and assess the cost of such work to the property involved.

With respect to the Menomonee River watershed, it is noteworthy that the City of Milwaukee Common Council has acted to create a Board of Harbor Commissioners to exercise the authority set forth in Sections 30.30 through 30.38 of the Wisconsin Statutes. The Board is composed of seven members, appointed by the mayor for three-year terms, subject to confirmation by the Common Council. The Board retains its own staff to carry out its activities, but its annual budget for operation and facility construction is subject to approval of the Common Council. The Milwaukee Harbor Commission's jurisdiction in the Menomonee River watershed encompasses the South Menomonee Canal, the Burnham Canal, and the Menomonee River to the fixed railroad bridges at approximately S. 26th and W. Canal Streets. City of Milwaukee jurisdiction and interest in the Menomonee River portion of the harbor area dates back to about 1869 when a canal commission was appointed by the mayor to fix the location of the canal and river bulkhead lines. As discussed in a later section of this chapter, there is no modern bulkhead line established by City ordinance on the Burnham Canal past S. 13th Street because of a conflict in the interpretation of the historic data describing the old bulkhead line in that area.

SPECIFIC LEGAL CONSIDERATIONS AND INVENTORY FINDINGS IN THE MENOMONEE RIVER WATERSHED

Certain specific legal questions were raised as work on the Menomonee River watershed proceeded. These dealt with the backing of floodwaters into established agricultural drains, interbasin water diversion, and private dams. In addition, inventories of work conducted with respect to state water regulatory permits, state water pollution abatement orders and permits, federal waste outfall permits, floodland regulation, flood insurance eligibility, and other local water-related regulatory matters.

Legal Implications of Temporarily Backing Flood Waters Into Agricultural Drains

One type of water control facility being considered for incorporation into the comprehensive plan for the Menomonee River watershed is the detention reservoir. While detention reservoirs sometimes provide a practical engineering approach to water control problems, the construction of such reservoirs presents certain legal problems which must be recognized and considered before a final plan selection is made. One of these concerns is the legal consequences of ponded water which may damage the improvements of drainage districts or nullify the effect of privately owned farm drains and tiles. A drainage district would have a cause for action if it could prove injury resulting from the backing of floodwaters into its drainage system. The legal remedy of damages can be employed even though the equitable remedy of injunction may not be available to prevent construction or use of detention reservoirs. From the standpoint of expediency and simplicity, the drainage district might negotiate the sale of a flowage right. If this is not feasible, an action can be brought by the drainage district each time that temporary flooding causing provable damage occurs. If the damage is permanent, that is, constitutes a "taking," the drainage district can initiate inverse condemnation proceedings.

The governmental unit considering construction of detention reservoirs seemingly has two approaches available to it. One of these might be called "active." Here the purchase of a flowage right is sought or condemnation proceedings commenced. An active approach has the advantage of doing today what might prove to be considerably more expensive if done at a later date. Furthermore, if any liability for damage appears imminent, it should be fixed and limited in advance, rather than left open and uncertain as to amount. The other general approach is just the opposite, an "inactive" or wait-and-see attitude. No actual injury to drainage districts may ever occur. Thus, simply building the detention reservoirs without seeking to condemn land or acquire flowage rights and dealing with any damage claims if and when they do arise may be the least costly and simplest way of proceeding.

While the above discussion refers to individual drainage districts acting on behalf of their constituent interests, individual farmers are in no way prevented from suing or acting on their own behalf either in law or in equity to preserve their interests in whatever drainage improvements they may have created on their lands.

Interbasin Water Diversion

One of the more important legal problems in water resources planning concerns interbasin diversion. The traditional common law riparian doctrine, which for the most part is still in effect today, forbade the transfer of water between watersheds. This was regarded as a non-riparian use of water. It must be recognized, however, that states by legislative action can and have created exceptions to this general doctrine and that major inter-watershed diversions, such as the so-called Chicago diversion of water from the Lake Michigan-St. Lawrence River drainage basin to the Mississippi River drainage basin, have on occasion taken place.

The problem of interbasin diversion was significant in the Commission watershed study for the Root and Fox Rivers, where alternative plan elements involved major interbasin water diversions. Such diversions are not, however, expected to be a factor in the preparation of alternative plan elements for the Menomonee River watershed.

Private Dams

One of the specific problems encountered in watershed planning programs involves the disposition of existing private dams. Such dams have created flowages or impoundments, and landowners whose lands abut the flowages have relied over a period of time on the artificial condition created by the dams. Often this reliance is evidenced by home and recreation facilities constructed in close proximity to, and because of, the flowed water. The Wisconsin Supreme Court has relatively recently restated the applicable law:

> If an artificial body of water is created, land owners incidentally benefited are entitled to injunctive relief to prevent disturbance of the new state of the water. Wisconsin prescriptive-rights cases involved proprietors of land which border on bodies of water, who in some way, relied on the new water level which was maintained by another's dam. These cases hold that when the artificial level of the water is continued for a considerable period of time, usually 20 years, it becomes a natural condition.[17]

So in cases where a dam created a flowage, which is now more than 20 years old, owners on the flowage seemingly are able to compel the owner of the dam to continue to maintain it.

A local unit of government or the State itself has only limited powers to compel the owners of private dams to maintain them. These powers are based on some combination of arguments involving the preservation of public rights in the flowage created, public health, safety, and welfare or, in some instances, the specific term or inferences which may be found in dam permits issued pursuant to statute by the appropriate state regulatory agency.

State Water Regulatory Permits

As noted earlier in this chapter, the Wisconsin Department of Natural Resources has broad authority under the Wisconsin Statutes to regulate the water resources of the State. An inventory was made under the Menomonee River watershed study of all permits issued by the Department and predecessor agencies in the Menomonee River watershed with respect to water regulation.

Bulkhead Lines: Municipalities are authorized by Section 30.11 of the Wisconsin Statutes to establish by ordinance bulkhead lines, subject to review and approval by the Wisconsin Department of Natural Resources. Bulkheads are required to conform as nearly as practicable near to existing shores and must be found by the Department of Natural Resources to be in the public interest. Only the City of Milwaukee in the Menomonee River watershed has established bulkhead lines. Nine separate bulkhead lines have been established by the City of Milwaukee, including five on the Menomonee River, two on the South Menomonee Canal, and two on Burnham Canal (see Table 97). These bulkhead lines are shown on Map 83. Interviews with officials of the Milwaukee Harbor Commission indicated that no modern bulkhead line has been established on that portion of the Burnham Canal west of S. 13th Street extended because of a conflict in the interpretation in historical data with respect to that area.

Waterway Enlargement and Protection: Except in Milwaukee County where the Milwaukee-Metropolitan Sewerage Commissions have sole jurisdiction, permits are required under Section 30.19 of the Wisconsin Statutes for work to establish any artificial waterway, canal, channel, ditch, lagoon, pond, lake, or other waterway where the purpose is a connection with a navigable body of water. In addition, permits are required under that Statute to connect any natural or artificially constructed

[17] *Tiedman v. Middleton, 25 Wis. 2d 443 (1964).*

waterway with an existing body of navigable water. Under Section 30.195 of the Wisconsin Statutes, permits are required for straightening or in any other way changing the course of a navigable stream. A total of five such permits have been issued in the watershed to date (see Table 98). Four of the permits were sought to change a streamcourse in order to accommodate urban development of varying types. One permit was sought for the construction of ponds adjacent to the Menomonee River. It should be noted that field observations reveal watercourse improvements apparently undertaken outside of Milwaukee County and not reflected in the permits identified in Table 98. This would seem to indicate that permits were not obtained for the channel improvement work.

Dam and Bridge Construction: Permits are required under Section 31.06 of the Wisconsin Statutes for the construction, operation, and maintenance of dams. In addition, permits are required under Section 31.23 of the Wisconsin Statutes for the construction of private bridges over streams greater than 35 feet in width. (Private bridges constructed over streams with a lesser width must receive plan approval from the Department of Natural Resources.) A total of three such permits have been issued under these Statutes in the Menomonee River watershed to date (see Table 99). Two of the three permits are for the two existing dams in the watershed, one operated by The Falk Corporation on the Menomonee River in the City of Milwaukee and the other operated by the Village of Menomonee Falls. The third permit is for maintenance of a timber bridge on the Menomonee River in the City of Milwaukee downstream of Hawley Road.

High Capacity Wells: Permits are required for non-municipal high capacity wells defined in Section 144.025 (2)(e) of the Wisconsin Statutes as a well or well field with facilities for withdrawing water at a rate of 100,000 gallons a day (70 gallons per minute) or more. A total of 22 such permits are known to have been issued in the watershed to date. These permits and their current status are summarized in Table 100.

Other Water Regulatory Permits: In a search of the records of the Wisconsin Department of Natural Resources, no permits were found in the Menomonee River watershed for the following types of water-related activities: placement of structures and deposits in navigable waters (Wisconsin Statutes Section 30.12); pierhead lines (Wisconsin Statutes Section 30.13); water diversion from lakes and streams (Wisconsin Statutes Section 30.18); dredging (Wisconsin Statutes Sections 30.20 and 30.205); water level control (Wisconsin Statutes Section 30.102); dam operation and maintenance (Wisconsin Statutes Section 31.07); raising or enlarging dams (Wisconsin Statutes Section 31.13); abandonment or transfer of dams (Wisconsin Statutes Section 31.185); complaints of dam insufficiency (Wisconsin Statutes Section 31.19); and dams on nonnavigable streams (Wisconsin Statutes Sections 31.12 and 31.33).

State Water Pollution Abatement Orders and Permits

An inventory was made of all effluent discharge permits and of all outstanding pollution abatement orders in the Menomonee River watershed. The following section presents the results of that inventory.

Table 97

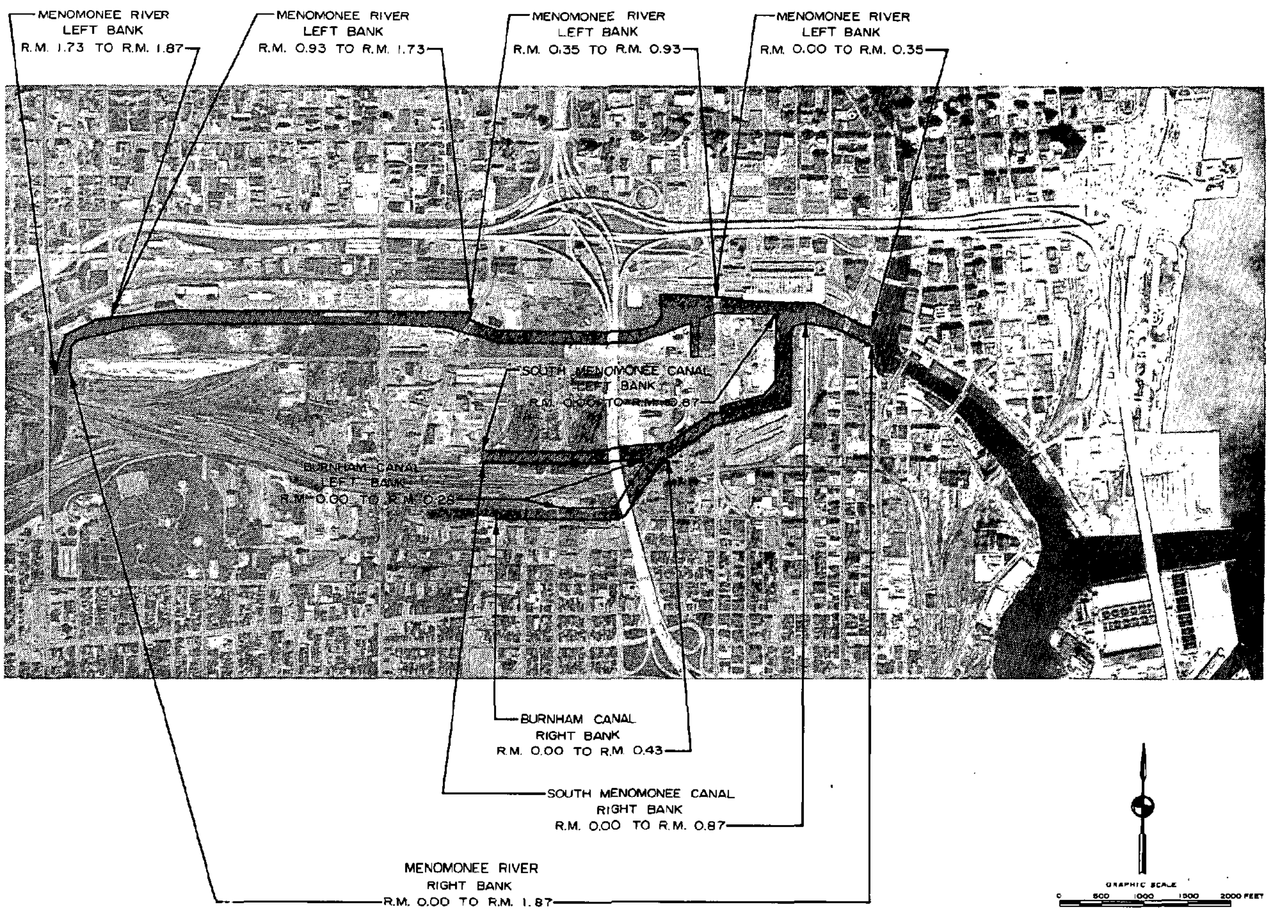
ESTABLISHED BULKHEAD LINES IN THE MENOMONEE RIVER WATERSHED: 1974

Civil Division	Watercourse	Location: River Mile From	River Mile To	Place Name From	Place Name To	Length (feet)	Dates of Approval: Municipality	Wisconsin Department of Natural Resources
City of Milwaukee	Menomonee River–Left Bank	1.73	1.87	N. 25th Street	W. Canal Street	874	September 30, 1969	October 14, 1969
	Menomonee River–Left Bank	0.93	1.73	N. Muskego Avenue	N. 25th Street	4,323	September 30, 1969	October 14, 1969
	Menomonee River–Left Bank	0.35	0.93	N. 6th Street	N. Muskego Avenue	3,408	November 14, 1967	No record of approval by WDNR or predecessor agencies
	Menomonee River–Left Bank	0.00	0.35	Milwaukee River Confluence	N. 6th Street	1,883	November 14, 1967	No record of approval by WDNR or predecessor agencies
	Menomonee River–Right Bank	0.00	1.87	Milwaukee River Confluence	W. Canal Street	10,414	December 1, 1964	No record of approval by WDNR or predecessor agencies
	South Menomonee Canal–Left Bank	0.00	0.87	Menomonee River Confluence	S. 13th Street Extended	4,561	March 23, 1962	May 9, 1962 by Public Service Commission
	South Menomonee Canal–Right Bank	0.00	0.87	Menomonee River Confluence	S. 13th Street Extended	4,759	March 23, 1962	May 9, 1962 by Public Service Commission
	Burnham Canal–Left Bank	0.00	0.28	South Menomonee Canal Confluence	S. 11th Street Extended	1,530	March 23, 1962	May 9, 1962 by Public Service Commission
	Burnham Canal–Right Bank	0.00	0.43	South Menomonee Canal Confluence	S. 13th Street Extended	2,323	January 9, 1969	February 5, 1971 (Informal approval only)

Source: City of Milwaukee Code of Ordinances (Chapter 8), Wisconsin Department of Natural Resources, and SEWRPC.

Map 83

ESTABLISHED BULKHEAD LINES IN THE MENOMONEE RIVER WATERSHED: 1975



Nine separate bulkhead lines have been established by the City of Milwaukee in the Menomonee River watershed. Five of the nine bulkhead lines are on the Menomonee River, two are on the South Menomonee Canal, and two are on the Burnham Canal.

Source: Wisconsin Department of Natural Resources, Milwaukee Harbor Commission, and SEWRPC.

Effluent Discharge Permits: As noted earlier in this chapter, a new Wisconsin pollution discharge elimination system permit structure has been established by the Wisconsin Department of Natural Resources pursuant to statutory authorization contained in Chapter 147 of the Wisconsin Statutes. A permit is required for all industrial and municipal waste discharges. The inventory revealed that to date (May 1975) a total of 44 industrial waste discharge permits have been applied for and/or issued in the Menomonee River watershed, together with a total of 132 municipal waste discharge permits. Pertinent characteristics pertaining to each of these permits are set forth in Tables 101 and 102, respectively.

Pollution Abatement Orders: In addition to the inventory of effluent discharge permits, an inventory was made of all outstanding pollution abatement orders in the Menomonee River watershed. Four such outstanding pollution abatement orders were found. One order has been issued to the Village of Butler and requires the Village to connect to the Milwaukee-Metropolitan sewerage system on a total flow basis when capacity in that system becomes available. A second order has been issued to the Chicago, Milwaukee, St. Paul, and Pacific Railroad Company and requires that company to construct an industrial waste treatment facility to eliminate the discharge of oil into the Menomonee River system. A third order has been issued to the Village of Germantown requiring the installation of phosphorus removal equipment at the Old Village sewage treatment facility. A fourth order has been issued to the Milwaukee-Metropolitan Sewerage Commissions and to constituent municipalities served by those commissions and concerns efforts to abate excessive clear water problems in their tributary sanitary sewerage systems.

Federal Waste Outfall Permits

The U. S. Department of the Army, Corps of Engineers, is authorized to issue permits for waste outfalls in navigable waters. Such permits are required because of the potential impact of such waste discharge structures on anchorage and navigation. To date a total of two such permits have been issued by the Corps of Engineers in the watershed. Permits have been issued to the A. L. Gebhardt Company and the United States Postal Service to construct waste outfalls which discharge into the estuary portion of the Menomonee River.

In addition to waste outfall permits, Section 404 of the Federal Water Pollution Control Act, as amended in 1972, grants authority to the Corps of Engineers to establish a permit system for the discharge of dredged or fill material into navigable waters, including adjacent wetlands. On July 25, 1975, the Corps published proposed rules to carry out this new responsibility. To date (September 1976) no permits for dredged or fill material discharged in the Menomonee River watershed have been issued.

Floodland Regulation

Even in the absence of definitive flood hazard data, such as that being developed under the Menomonee River watershed study, several communities in the watershed have taken steps properly to zone riverine areas against incompatible urban development. In particular, the Villages of Elm Grove, Germantown, and Menomonee Falls and the Cities of Mequon, Brookfield, Milwaukee, and

Table 98

WATERWAY ENLARGEMENT AND PROTECTION AND STREAM COURSE CHANGING PERMITS IN THE MENOMONEE RIVER WATERSHED: 1975

Permit Recipient	Location of Project		Watercourse	Type of Project	Purpose of Project	Date Permit Issued	Legal Authority
	Civil Division	U. S. Public Land Survey Quarter Section					
J. Bence	Village of Menomonee Falls	NE 1/4, Section 10, T8N, R20E	Menomonee River	Change Stream Course	Accommodate Road Design for Residential Subdivision	August 12, 1963	Section 30.195 Wisconsin Statutes
Butler Industrial Land Company . .	Village of Butler	NE 1/4, Section 36, T8N, R20E	Menomonee River	Change Stream Course	Accommodate Industrial Park Development	June 11, 1964	Section 30.195 Wisconsin Statutes
Village of Butler.	Village of Butler	E 1/2, Section 36, T8N, R20E	Menomonee River	Change Stream Course	Accommodate Village Park Development	December 21, 1965	Section 30.195 Wisconsin Statutes
Village of Butler.	Village of Butler	E 1/2, Section 36, T8N, R20E	Menomonee River	Change Stream Course	Accommodate Village Park Development	January 28, 1966	Section 30.195 Wisconsin Statutes
Germantown Joint School District No. 1 . . .	Village of Germantown	E 1/2, SW 1/4, Section 21, T9N, R20E	Menomonee River	Construct Ponds Adjacent to River	Create Fish and Wildlife Habitat, Aesthetics	November 9, 1970	Section 30.19 Wisconsin Statutes

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 99

DAM AND PRIVATE BRIDGE CONSTRUCTION PERMITS IN THE MENOMONEE RIVER WATERSHED: MAY 1975

Permit Recipient	Location		Watercourse	Type of Project	Purpose of Project	Date Permit Issued	Legal Authority	Special Conditions
	Civil Division	River Mile						
The Falk Corporation	City of Milwaukee	2.22	Menomonee River	Dam Construction and Operation	Create Reservoir for Industrial Water Supply	November 8, 1941	Section 31.05 Wisconsin Statutes	Spillway Crest Set at 580.44 feet msl
Village of Menomonee Falls	Village of Menomonee Falls	21.98	Menomonee River	Dam Reconstruction and Operation	Create Pool for Park and Recreation and Emergency Water Supply	September 2, 1952	Section 31.05 Wisconsin Statutes	Normal Pond Elevations to be Maintained Between 832.0 and 833.0 feet msl
Manegold Stone Company	City of Milwaukee	4.88	Menomonee River	Relocate and Maintain a Timber Bridge	Provide River Crossing for Mineral Extraction Operation	November 30, 1946	Section 31.23 Wisconsin Statutes	--

Source: Wisconsin Department of Natural Resources and SEWRPC.

Wauwatosa have taken steps through conservancy zoning to protect lands that have been historically flooded. Upon completion of the watershed study and the consequent availability of more definitive data on the extent of the 100-year recurrence interval floodplain in the watershed, it will be necessary for these communities, as well as the other communities having riverine area in the watershed, to take appropriate steps to more adequately protect the natural floodlands in the watershed.

Flood Insurance Eligibility

At the present time, every community in the Menomonee River watershed has taken the steps to become eligible for participation in the federal flood insurance program. Federal flood insurance studies to determine actuarial rates to be applied in several of the communities in the Menomonee River watershed have begun and will be fully coordinated with the recommendations contained in the Menomonee River watershed study.

Table 100

KNOWN HIGH-CAPACITY WELL PERMITS IN THE MENOMONEE RIVER WATERSHED: 1975

USGS Number	Well[a] Location: Town/Range	Section	Quarter Section	Permit Recipient	Year Drilled	Type of Use	Authorized Pumpage in Gallons Per Day
				Milwaukee County			
549	0721	6	2	S. K. Williams Company	1968	Industrial	248,000
324	0721	7	4	A & P Food Stores	1954	Industrial	20,000
349	0721	7	4	Wisconsin Cold Storage Company	1954	Commercial	250,000
351	0721	7	3	Briggs & Stratton Company	1955	Industrial	865,000
443	0721	7	2	The Falk Corporation	1958	Industrial	437,000
483	0721	30	4	Holiday Inn	1960	Commercial	15,000
321	0721	31	1	Kearney & Trecker Corporation	1953	Industrial	320,000
492	0722	32	2	Milwaukee Tallow & Grease Company	1961	Industrial	392,000
				Ozaukee County			
354	0921	29	4	Resurrection Cemetery	1967	Irrigation	221,000
				Washington County			
47	0920	22	1	Germantown Volunteer Fire Department, Inc.	1960	Fire Protection	720,000
48	0920	22	4	Germantown Volunteer Fire Department, Inc.	1960	Fire Protection	720,000
				Waukesha County			
712	0720	1	4	Milwaukee Electric Tool Company	1968	Industrial	50,000
242	0720	11	1	City of Brookfield	1965	Fire Protection	2,000
228	0720	12	1	J. C. Penney Company, Inc. Treasure Island Shopping Center	1964	Commercial	24,000
187	0720	14	4	Mt. Zion Cemetery	1961	Irrigation	14,400
234	0720	15	4	City of Brookfield	1965	Domestic and Irrigation	65,000
889	0720	24	3	Village of Elm Grove	1960	Domestic	60,000
146	0720	25	1	Sisters of Notre Dame Convent	1956	Domestic	144,000
716	0720	25	1	D. G. Beyer, Inc. (UPS)	1968	Commercial	93,500
161	0720	25	4	W. A. Krueger Company	1958	Industrial	79,000
212	0820	13	2	North Hills Country Club	1962	Irrigation	75,600
246	0820	13	3	North Hills Country Club	1963	Irrigation	200,000

[a] *Limited to industrial, commercial, agricultural, and other private wells for which the Wisconsin Department of Natural Resources had well permits on file as of September 1975.*

Source: U. S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

Table 101

INDUSTRIAL WASTE DISCHARGE PERMITS ON FILE[a] IN THE MENOMONEE RIVER WATERSHED: MAY 1975

Permittee[b]	Location[b] Address	Location[b] Civil Division	Type of[b] Discharge	Pretreatment[b] (If Known)	Receiving[b] Stream	Permit[b] Number
AMF, Inc. - Harley Davidson Motor Company.	11700 W. Capitol Drive	City of Wauwatosa	Cooling and Wash Water		Menomonee River via Unnamed Tributary	WI-0000213
Amoco Oil Company Bulk Plant	360 S. Curtis Road	City of West Allis	Wash Water	Oil and Water Separator	Groundwaters of Menomonee River Watershed	WI-0051047
Babcock and Wilcox, Tubular Products Division	3839 W. Burnham Street	City of Milwaukee	Cooling Water		Menomonee River via Storm Sewer	WI-0030171
Briggs & Stratton Corporation	3300 N. 124th Street	City of Wauwatosa	Process Water		Menomonee River via Storm Sewer	WI-0026514
Butler Lime & Cement Compnay.	12005 W. Hampton Avenue	City of Milwaukee	Wash Water	Settling Basin	Menomonee River via Storm Sewer	WI-0022632
Carnation Company-Can Division	N90 W14600 Commerce Drive	Village of Menomonee Falls	Cooling Water		Menomonee River via Storm Sewer	WI-0038059
Center Fuel Company . .	3015 W. Center Street	City of Milwaukee	Storm Water and Fuel Oil and Gasoline Spills	Oil and Water Separator	Little Menomonee River via Storm Sewer	WI-0034231
Chicago & Northwestern Railway Company	4823 N. 119th Street	Village of Butler	Process Water and Storm Water	Oil and Water Separator	Menomonee River via drainage ditch	WI-0027171
Chicago, Milwaukee, St. Paul, and Pacific, Railroad Company	3301 W. Canal Street	City of Milwaukee	Process Water and Storm Water		Menomonee River via Storm Sewer	WI-0027057
Chr. Hansen Laboratory, Inc..	9015 W. Maple Street	City of West Allis	Cooling Water		Honey Creek via Storm Sewer	WI-0027341
Continental Equipment Corporation	6103 N. 76th Street	City of Milwaukee	Cooling Water		Menomonee River via Storm Sewer	WI-0033227
The Falk Corporation . .	3001 W. Canal Street	City of Milwaukee	Process Water		Menomonee River via Storm Sewer	WI-0001139
The Falk Corporation . .	270 N. 12th Street	City of Milwaukee	Cooling Water		Menomonee River via Storm Sewer	WI-0038555
The Falk Corporation . .	12001 W. Capitol Drive	City of Wauwatosa	Cooling Water and Process Water		Menomonee River via Tributary	WI-0038563
Federal Malleable Company.	8055 S. 72nd Street	City of West Allis	Cooling Water and Process Water		Menomonee River via Storm Sewer	WI-0027628
Gehl Guernsey Farms, Inc..	N116 W16686 Main Street	Village of Germantown	Cooling Water		Menomonee River via Storm Sewer	WI-0033219
Grede Foundries, Inc. . .	6432 W. State Street	City of Wauwatosa	Cooling Water		Menomonee River via Storm Sewer	WI-0026581
Grey Iron Foundry, Inc.	1501 S. 83rd Street	City of West Allis	Cooling Water and Process Water		Honey Creek via Storm Sewer	WI-0000507
Harnischfeger Corporation	4400 W. National Avenue	City of Milwaukee	Cooling Water		Menomonee River via Storm Sewer	WI-0025321
Hentzen Chemical Coatings, Inc.	6937 W. Mill Road	City of Milwaukee	Cooling Water		Little Menomonee River vis Storm Sewer	WI-0038075
Inland-Ryerson Construction Products Company	4101 W. Burnham Street	City of Milwaukee	Cooling Water		Menomonee River via Storm Sewer	WI-0034657
Kearney & Trecker Corporation	11000 Theodore Trecker Way	City of West Allis	Cooling Water		Underwood Creek via Storm Sewer	WI-0033146
Marquette Cement Manufacturing Company.	745 W. Canal Street	City of Milwaukee	Cooling Water and Process Water	Electrostatic Precipitation	South Menomonee Canal via Storm Sewer	WI-0001490
Marquette University . . .	517 N. 14th Street	City of Milwaukee	Cooling Water and Steam Condensate		Menomonee River via Storm Sewer	WI-0033715
Miller Brewing Company.	4000 W. State Street	City of Milwaukee	Cooling Water		Menomonee River via Storm Sewer	WI-0000744

Table 101 (continued)

Permittee[b]	Location[b] Address	Civil Division	Type of[b] Discharge	Pretreatment[b] (If Known)	Receiving[b] Stream	Permit[b] Number
Milwaukee County Institutions— Power Plant	9050 Watertown Plank Road	City of Wauwatosa	Cooling Water and Process Water		Menomonee River via Drainage Ditch	WI-0039268
Milwaukee Marble Company— Manufacturing Plant . . .	122 N. 27th Street	City of Milwaukee	Process Water		Menomonee River via Storm Sewer	WI-0000809
Mobil Oil Corporation— Milwaukee Lube Plant . .	1547 S. 38th Street	City of Milwaukee	Cooling Water and Storm Water	Oil and Water Separator	Menomonee River via Storm Sewer	WI-0034444
Molded Rubber & Plastic Corporation	13161 W. Glendale Avenue	Village of Butler	Cooling Water		Menomonee River via Storm Sewer	WI-0033189
Murphy Diesel Company.	5317 W. Burnham Street	City of Milwaukee	Cooling Water		Menomonee River via Storm Sewer	WI-0026531
The Perlick Company, Inc..	8300 W. Good Hope Road	City of Milwaukee	Cooling Water		Menomonee River via Unnamed Tributary	WI-0037745
Pressed Steel Tank Company[c].	1445 S. 66th Street	City of West Allis	Process Water		Discharge to Sanitary Sewer	WI-0039489
Rexnord, Inc.	4701 W. Greenfield Avenue	Village of West Milwaukee	Cooling Water and Process Water		Menomonee River via Storm Sewer	WI-0026573
Robert A. Johnston Company.	4023 W. National Avenue	City of Milwaukee	Cooling Water		Menomonee River via Storm Sewer	WI-0038644
Safer Cleaning Center. . .	13805 W. Capitol Drive	City of Brookfield	Cooling Water		Menomonee River via Storm Sewer	WI-0033171
Safeway Wash-A-Car, Incorporated.	8411 W. Lincoln Avenue	City of West Allis	Process Water	Grease Trap and Catch Basin	Menomonee River via Storm Sewer	WI-0033847
S. K. Williams Company.	4600 N. 124th Street	City of Wauwatosa	Process Water and Cooling Water		Menomonee River via Storm Sewer	WI-0026204
Union Oil Company of California	9521 N. 107th Street	City of Milwaukee	Storm Water	Oil and Water Separator	Little Menomonee River via Drainage Ditch	WI-0038113
United Waste Systems . .	9050 N. 124th Street	City of Milwaukee	Landfill Leachate	Holding Pond	Menomonee River via Tributary	WI-0037494
W. A. Krueger Company, Incorporated.	12821 W. Bluemound Road	City of Brookfield	Cooling Water		Underwood Creek via Drainage Ditch	WI-0027065
Western Metal Specialty Division Western Industries, Inc. .	1211 N. 62nd Street	City of Wauwatosa	Cooling Water		Menomonee River via Storm Sewer	WI-0039004
Western States Envelope Company	4480 N. 132nd Street	Village of Butler	Cooling Water		Menomonee River via Storm Sewer	WI-0039365
Wisconsin Electric Power Company.	1035 W. Canal Street	City of Milwaukee	Cooling Water and Process Water		South Menomonee Canal	WI-0000931
Wisconsin Electric Power Company.	231 W. Michigan Street	City of Milwaukee	Steam Condensate		Menomonee River via Storm Sewer	WI-0001686

[a] *Includes Wisconsin Pollution Discharge Elimination System (WPDES) permit applications on file as of May 1975.*

[b] *Information taken directly from WPDES permit or permit application.*

[c] *The Pressed Steel Tank Company was subsequently determined to not require a WPDES permit as all its wastes are discharged into a sanitary sewer.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Other Local Water-Related Regulatory Matters

An inventory was conducted under the Menomonee River watershed study of other local ordinances relating to water quality and water use. This inventory indicated that the rules of the Sewerage Commission of the City of Milwaukee and the Metropolitan Sewerage Commission of the County of Milwaukee prohibit the discharge of storm water and all other unpolluted drainage into the sanitary sewer system, except that which is specifically designed as part of a combined sewer system. In addition, the rules of the joint sewerage Commissions require that every municipality contributing sanitary sewage to the

Table 102

MUNICIPAL WASTE DISCHARGE PERMITS ISSUED IN THE MENOMONEE RIVER WATERSHED: MAY 1975

Permittee	Permit Number	Receiving Stream	Type of Discharge	Location
Village of Butler Sewer Utility	WI-0025364	Menomonee River	Wastewater Overflow-Chlorination Facility	N. 124th Street and Villard Avenue
Village of Germantown.	WI-0020567	Menomonee River	Municipal Sewage Treatment Plant	N116 W17230 Main Street
Village of Menomonee Falls. . .	WI-0025381	Menomonee River	Municipal Sewage Treatment Plant	N85 W15382 Menomonee River Parkway (Pilgrim Road Plant)
			Municipal Sewage Treatment Plant	N81 W13800 Parkview Drive (Lilly Road Plant)
			Bypass	Arthur Avenue and Menomonee River
				Pilgrim Road and Menomonee River (North)
				Pilgrim Road and Menomonee River (South)
			Crossover-Sanitary Sewer	Donald Court and May Avenue
				Main Street and Pilgrim Road
			Portable Pumping Station	Ann Avenue and Sheridan Drive
				Water Street and Milwaukee Road Railroad
				Menomonee Avenue and Norman Drive
				Joss Place and Sheridan Drive
				Hillcrest Drive and Sheridan Drive
				Roosevelt Drive and Caroline Drive
				Water Street and Cherokee Drive
				Hope Lane and Shepherd Drive
				Queensway and Klinger
				St. Francis Drive and Roosevelt Drive
			Relief Pumping Station	Parkview Drive at Wastewater Treatment Plant
				Shady Lane north of Grand Avenue
				Grand Avenue and Woodlawn Avenue
				Grand Avenue and Roger Avenue
Village of Menomonee Falls . . .	WI-0037192	Menomonee River	Water Treatment Plant Backwash	W152 N8634 Margaret Road
City of Milwaukee . .	WI-0026785	Menomonee River	Combined Sewer Outfall	S. Second Street
				S. Muskego Avenue
				S. Muskego Avenue
				N. Ninth Street extended-S. Stadium Access Road (250 feet east of S. 44th Street)
				N. 15th Street
				N. 15th Street
				N. 17th Street
				N. 25th Street
				N. 26th Street
				S. 27th Street
				S. 27th Street
				S. 35th Street
				W. Wisconsin Avenue
				W. Wisconsin Avenue
				N. 43rd Street
				N. 45th Street
				N. Hawley Road
		Burnham Canal	Combined Sewer Outfall	S. Ninth Street
				S. Ninth Street
				S. 11th Street
				S. 13th Street
				S. 13th Street
				S. Muskego Avenue
		S. Menomonee Canal	Combined Sewer Outfall	S. Fourth Street
				S. Sixth Street

Table 102 (continued)

Permittee	Permit Number	Receiving Stream	Type of Discharge	Location
City of Milwaukee (continued).	WI-0026785	Menomonee River	Crossover-Sanitary Sewer	N. 68th Street and W. Center Street
				N. 79th Street and W. Locust Street
				W. Center Street at N. 86th Street
				N. 76th Street 200 feet north of W. Hadley Street
				W. Center Street at N. 88th Street
				N. 89th Street at W. Townsend Street
				N. 90th Street at W. Townsend Street
				W. Dickinson Street and S. 62nd Street
				W. Stevenson Street and N. 71st Street
				W. Mt. Vernon Avenue and N. 69th Street
				W. Hadley Street at N. 80th Street
				W. Mt. Vernon Avenue 75 feet east of N. 91st Street
				N. 92nd Street and W. Hawthorne Avenue
				N. 92nd Street and W. Park Hill Avenue
				N. 94th Street and W. Townsend Street
				N. 95th Street and W. Metcalf Place
				N. 89th Street and W. Center Street
				N. 87th Street and W. Center Street
			Crossover-Combined Sewer	N. 37th Street 145 feet north of W. Mt. Vernon Avenue
				N. 38th Street and W. Mt. Vernon Avenue
				N. 46th Street and W. State Street
				W. Hilda Place and S. 38th Street
			Portable Pumping Station	N. 96th Street at W. Auer Avenue
				N. 99th Street at W. Concordia Avenue
		Little Menomonee River	Portable Pumping Station	W. Monrovia Avenue at W. Crossfield Avenue
		Honey Creek	Portable Pumping Station	S. 72nd Street and W. Honey Creek Parkway
				S. 77th Street and W. Oklahoma Avenue
City of Brookfield . .	WI-0023469	Underwood Creek	Portable Pumping Station	Robinwood Street and Cardinal Crest Drive
				Pinewood Road and Princeton Road
				Rosedale Drive and Bluemound Road
City of Wauwatosa . .	WI-0031071	Menomonee River	Crossover-Sanitary Sewer	Ridge Boulevard and N. Harding Boulevard
				W. North Avenue and Menomonee River Parkway
				Jackson Park Boulevard and Swan Boulevard
				Jackson Park Boulevard and N. 90th Street
				Jackson Boulevard and N. 85th Street
				W. North Avenue and N. 82nd Street
				W. Meinecke Avenue and N. 83rd Street
				Stickney Avenue and N. 85th Street
				Stickney Avenue and N. 90th Street
				Swan Boulevard and Menomonee River Parkway
				N. 90th Street and Menomonee River Parkway
				Ludington Avenue and Hoyt Park
				Hillcrest Drive and N. 85th Street
				Milwaukee Avenue and N. 72nd Street
				Martin Drive and N. 62nd Street
				N. 62nd Street south of Martin Drive
				East end of Hillside Lane
				N. 65th Street and W. Wisconsin Avenue
				N. 68th Street and W. Wisconsin Avenue
				N. 70th Street and W. Center Street
				N. 105th Street and W. Ruby Avenue
				W. Concordia Avenue and N. Menomonee River Parkway
				N. 67th Street and W. Wells Street
				W. Meinecke Avenue from N. 83rd Street to N. 86th Street

Table 102 (continued)

Permittee	Permit Number	Receiving Stream	Type of Discharge	Location
		Honey Creek	Crossover-Sanitary Sewer	Glenview Avenue and Currie Avenue Ravenswood Circle and N. 89th Street Glenview Avenue and Hawthorne Avenue Honey Creek Parkway and W. Wisconsin Avenue Glencoe Place and Ravenswood Circle N. 85th Street between Hill Street and Ravenswood Circle
		Underwood Creek	Crossover-Sanitary Sewer	N. 106th Street and W. Fisher Parkway
		Menomonee River	Portable Pumping Station	Ravenswood Circle and N. 85th Street N. 106th Street and W. Ruby Avenue East end of Hillside Lane N. 71st Street and W. State Street N. 65th Street and W. Wisconsin Avenue Menomonee River Parkway and N. 90th Street W. Keefe Avenue and N. Menomonee River Parkway W. Argonne Drive and W. Concordia Avenue W. Concordia Avenue and N. Menomonee River Parkway (East) W. Concordia Avenue and N. Menomonee River (West)
		Honey Creek	Portable Pumping Station	W. Wisconsin Avenue and W. Honey Creek Parkway Ravenswood Circle and Glencoe Circle
		Underwood Creek	Portable Pumping Station	N. 118th Street and Watertown Plank Road N. 104th Street and W. Wisconsin Avenue N. 106th Street and W. Fisher Parkway N. 104th Street and W. Fisher Parkway N. 115th Street south of Watertown Plank Road N. 121st Street and W. Underwood Parkway N. 116th Street and Diane Drive
City of West Allis . . .	WI-0030678	Honey Creek	Crossover-Sanitary Sewer	S. 77th Street and W. Walker Street S. 78th Street extended and W. Madison Street S. 78th Street and W. Arthur Avenue

Source: Wisconsin Department of Natural Resources and SEWRPC.

metropolitan sewerage system adopt effective ordinances prohibiting the discharge of clear water into the sanitary sewerage system. The inventory further revealed that nearly all municipalities in the watershed have such clear water elimination ordinances in addition to ordinances prohibiting the discharge of deleterious materials and substances to the sanitary sewer system.

In addition, the inventory indicated that the Milwaukee County Board of Supervisors and the Milwaukee County Park Commission have adopted rules and regulations affecting parks and parkways and the use of such areas relative to water-related recreational activities. These rules provide that, except upon the express permission of the Park Commission, no person shall fish the waters of the parks or the parkways. In addition, no person shall, without the express written permission of the Park Commission, place upon the lagoons, rivers, or any of the waters under the control of the Park Commission any float, boat, or other water craft, nor may one land or go upon any of the islands of the lagoons or rivers nor land or touch with a boat upon any of the shoreline in a parkway not specifically designated as a landing place.

Under Section 30.77 of the Wisconsin Statutes, any town, village, or city may adopt local boating regulations not inconsistent with specified uniform statewide regulations set forth in Sections 30.50 through 30.71 of the Wisconsin Statutes. Such local supplementary boating regulations may pertain to the equipment, use, and operation of a boat on a navigable body of water, including rivers and streams. Such regulations must be found to be in the interest of public health, safety, or welfare. Under this basic statutory authorization, it would appear that any municipality in the Menomonee River watershed could enact local boating regulations that would, for example, prohibit the operation of boats and other water craft during flooding periods. Such regulations would be related directly to public health and safety in that they would be designed to protect individuals from dangerous conditions during periods of flooding and consequent rapid water movement. The regulations could be so written as to be placed into effect when a prespecified flood stage or elevation was reached. Inventories conducted under the Menomonee River watershed study did not reveal the existence of any such boating regulations in the watershed.

SUMMARY

This chapter has described in summary form the legal framework within which comprehensive watershed planning and plan implementation must take place in southeastern Wisconsin. The salient findings having particular importance for planning in the Menomonee River watershed include the following:

Water law is not a simple or fixed body of law. It has historical roots which reach back beyond the common law. Three principal divisions of water law may be identified: riparian and public rights law, groundwater law, and diffuse surface water law. Riparian and public rights law applies to the use of surface water occurring in natural rivers, streams, lakes, and ponds. Groundwater law applies to the use of water occurring in the saturated zone below the water table. Diffuse surface water law applies to water draining over the surface of the land. The field of water law has never been in a greater or more continuous state of change than it has today. In 1974 alone, the Wisconsin Supreme Court in landmark cases expressly overruled the historic common law doctrine with respect to both groundwater law and diffuse surface water law, finding that the historic doctrines no longer applied to modern water resource problems and conflicts.

With passage of the Federal Water Pollution Control Act Amendments of 1972, the U. S. Congress set in motion a series of actions which will have many ramifications for water quality management within the Region and the Menomonee River watershed. Water use objectives and supporting water quality standards now are required for all navigable waters in the United States. It is a national goal to eliminate the discharge of pollutants into the navigable waters of the United States by 1985. To meet this goal, the Act requires the enactment of specific effluent limitations for all point sources of water pollution. The Act also establishes a pollutant discharge permit system to issue permits for the discharge of any pollutants subject to conditions that the discharge meet all applicable effluent limitations and contribute toward achieving the water use objectives and supporting water quality standards.

Responsibility for water quality management in Wisconsin is centered in the Wisconsin Department of Natural Resources. The Department is given authority to prepare long-range water resources plans, to establish water use objectives and supporting water quality standards applicable to all waters of the State, to establish a pollutant discharge permit system, and to issue pollution abatement orders. New water use objectives and supporting water quality standards applicable to all of the surface waters of the Menomonee River watershed were adopted by the Wisconsin Natural Resources Board in 1973. With respect to the Menomonee River watershed, the water use objectives, recognizing the nature and concentration of riverine development as well as the existing watercourse improvements, include the application of the restricted use category to Honey Creek, Underwood Creek, and the main stem of the Menomonee River downstream from its confluence with Honey Creek.

In addition to the broad grant of authority to general purpose units of local government to regulate in the interests of health, safety, and welfare, the Wisconsin Statutes currently provide for the creation of five types of special purpose units of government through which water pollution can be abated and water quality protected. These special units of government are the Metropolitan Sewerage District of the County of Milwaukee, other metropolitan sewerage districts, utility districts, joint sewerage systems, and cooperative action by contract. The Metropolitan Sewerage District of the County of Milwaukee has authority extending over the entire Menomonee River watershed and represents for all practical purposes the single entity responsible for the conveyance and treatment of sanitary sewage in the Menomonee River watershed. The cooperative action by contract power has been utilized in the Menomonee River watershed by the City of Brookfield and the Villages of Elm Grove and Menomonee Falls to provide for the construction, operation, and maintenance of intercommunity trunk sewers.

The effective abatement of flooding can only be achieved by a comprehensive approach to the problem. As urbanization proceeds within a watershed, it becomes increasingly necessary to develop an integrated program of land regulation of the floodlands of the entire watershed to supplement required water control facilities if efforts to provide such facilities are not self-defeating. The Commission has recommended that the natural floodplains of a river or stream be specifically defined as those appropriate to a flood having a recurrence interval of 100 years. Under ideal regulatory conditions, the entire natural floodlands would be maintained in an open, essentially natural state and would not be filled and utilized for incompatible, intensive urban land uses. The enactment of sound floodway and floodplain fringe regulations is required under the state floodplain management program and for municipal participation in the federal flood insurance program. A Governor's Executive Order designed to promote a unified state policy of floodplain management requires that all state agencies appropriately take into account flood hazards and local floodplain regulations in state agency actions.

Flood control facilities may be constructed in the Menomonee River watershed either through cooperative action by contract of the local municipalities or by the use of special purpose districts. Such districts include the Metropolitan Sewerage District of the County of Milwaukee, which has historically carried out extensive drainage course improvements in the Menomonee River watershed; flood control boards; and soil and water conservation districts.

Inventories were conducted under the Menomonee River watershed study for state water regulatory permits issued in the watershed under Chapters 30 and 31 of the Wisconsin Statutes, as well as for permits for high-capacity wells issued under Chapter 144 of the Wisconsin Statutes. In addition, inventories were conducted with respect to state effluent discharge permits, state pollution abatement orders, and federal waste outfall permits.

Chapter XI

SUMMARY

STUDY ORGANIZATION AND PURPOSE

The Menomonee River watershed study, which resulted in the preparation of this report, is the fourth comprehensive watershed planning program to be undertaken by the Southeastern Wisconsin Regional Planning Commission. This watershed study was undertaken within the statutory authority of the Commission and upon the request and approval of the local units of government concerned. The study was guided from its inception by the Menomonee River Watershed Committee, an advisory Committee to the Commission, composed of 19 elected and appointed public officials, technicians, and citizen leaders from throughout the watershed.

The technical work was carried out by the Commission staff with the assistance of cooperating governmental agencies, including the U. S. Department of the Interior, Geological Survey, and the Wisconsin Department of Natural Resources; and private consultants engaged by the Commission, including Hydrocomp, Inc., of Palo Alto, California, and Alster & Associates, Inc., of Madison, Wisconsin. Each of these organizations was selected by the Commission for participation in the watershed planning program because of its skills and experience in specialized phases of water resources planning and engineering. The disciplines provided included specialization in ground and surface water hydrology and hydraulics, ecology and natural resource conservation, simulation modeling, and control survey and photogrammetric engineering.

The study was founded upon the recognition by concerned public officials that such problems, as flooding and water pollution transcend local governmental boundaries and that solutions to such areawide problems must be sought on a watershed basis. Furthermore, it was recognized that the water and water-related resource problems of the Menomonee River watershed are directly and inextricably interrelated, not only with each other, but also with problems of areawide urbanization and with the associated increasing, and sometimes misdirected, demands upon the natural resource base.

The primary purpose of the Menomonee River watershed planning program is to assist the federal, state, and local units of government in abating the serious water and water-related resource problems of the Menomonee River watershed by developing a workable plan to guide the staged development of multipurpose water resource-related facilities and related resource conservation and management programs for the watershed. More specifically, the objectives of the planning program are to:

1. Prepare a plan for the management of floodlands along the major waterways of the watershed; the plan will identify and recommend measures for both the mitigation of existing flood problems and the avoidance of new flood problems.

2. Prepare a plan for surface and groundwater quality management for the watershed; the plan will identify and recommend measures for both the abatement of existing water pollution problems and the prevention of future water pollution problems.

3. Prepare a plan for public open-space reservation and for recreational development within the watershed; the plan will identify and recommend measures for the preservation and enhancement of the remaining woodlands, wetlands, and fish and wildlife habitat of the watershed.

4. Refine and adjust the adopted regional land use plan to reflect the conveyance, storage, and waste assimilation capabilities of the perennial waterways and floodlands of the watershed, recognizing in such refinements the potential effects of any recommended water control facilities and seeking to promote the rational adjustment of land uses in this urbanizing basin to the ability of the water and water-related natural resources to sustain such uses without creating further environmental or developmental problems.

A fifth objective—the preparation of a plan for water supply within the watershed—was set forth in the Menomonee River watershed planning program prospectus and in Chapter 1 of this volume. Inventories and analyses of domestic and industrial water use and supply in the watershed, as described in Chapter VII of this volume, indicate that the water supply problems that do exist within the watershed and which may be expected to develop within the watershed over the planning period are either being adequately addressed by the governmental agencies concerned, or must be addressed on a broader regional basis. Eighty percent of the watershed population receives an adequate and safe supply of Lake Michigan water through four public water utilities—the Milwaukee Water Works, the Wauwatosa Water Works, the West Allis Water Utility, and the Greendale Water and Sewer Utility. Six percent of the watershed population is served by the following four public utilities which rely on groundwater as the source of supply: the Germantown Water Utility, the Menomonee Falls Water Utility, the Butler Water Utility, and the Brookfield Water Utility. None of these utilities currently is experiencing serious water quantity or quality problems nor are such problems expected to develop in the near future. Furthermore, these and other communities presently, are jointly investigating the possibility of development of an inter-municipal water supply system utilizing Lake Michigan as a source of supply. The remaining 14 percent of the watershed population is served by private groundwater supplies which generally use relatively shallow wells. Potential pollution and aesthetic problems associated with these wells will be largely resolved through provision of sanitary sewerage service as recommended in the adopted Regional Sanitary Sewerage System Plan for Southeastern Wisconsin.

Some industrial water users in the watershed are self-supplied in that they satisfy all or part of their water needs from private wells or by pumping directly from the stream system with the principal use of this water being for cooling purposes. The latter pumpages by The Falk Corporation and the Wisconsin Electric Power Company occur in the lower reaches of the watershed and have a combined pumpage rate that is equivalent to less than 1 percent of the average annual discharge of the Menomonee River Watershed. These two surface water users can continue to be supplied without creating any serious water use conflicts. Investigations carried out under the watershed study indicate that self-supplied industrial-commercial water users are not experiencing any serious quantity or quality problems nor is the pumping interfering with that of the four groundwater utilities on surface water uses. In summary, because of the absence of existing serious residential or industrial water supply problems within the watershed and because of certain measures underway to resolve the anticipated future problems that may occur, it was concluded that there was no need to include a water supply plan element in the comprehensive plan for the Menomonee River Watershed.

If the watershed plan is to be effective in abating problems of water pollution, soil erosion, deteriorating fish and wildlife habitat, flood damage, dwindling open space, and changing land use within the watershed, it must be receptive to cooperative adoption and joint implementation by all levels and agencies of government concerned and it must be capable of functioning as a practical guide to the making of development decisions for both land use and water control facility development within the watershed on a day-to-day basis. Accordingly, the watershed study has been broad in scope and detailed in content, and a full range of scientific disciplines has been applied to the tasks of study design; formulation of watershed development objectives and standards; inventory, analysis, and forecasts; plan design; plan test and evaluation; and plan selection and adoption.

The major findings and recommendations of the four-year comprehensive watershed planning program are presented in a two-volume planning report. This, the first volume of the report, sets forth the basic concepts underlying the study and presents in summary form the factual findings of the extensive inventories conducted under the study. It identifies and, to the extent possible, quantifies the developmental and environmental problems of the watershed and sets forth forecasts of future economic activity, population growth, and concomitant land use and natural resource demands. The second volume of the report presents the watershed development objectives and standards, alternative land use and water control facility plan elements, and a recommended comprehensive watershed development plan, together with recommendations concerning the best means for the implementation of that plan.

The report can only summarize in brief fashion the large volume of information assembled in, and the recommendations growing out of, the extensive data collection, analysis, forecasting, plan design, and plan evaluation phases of the Menomonee River watershed study. Although, reproduction of the complete study data files in published format is impossible due to the volume and complexity of the data collected, all of the data are generally available to member units and agencies of government from the Commission files upon specific request.

INVENTORY, ANALYSIS, AND FORECAST FINDINGS

Geography

The Menomonee River watershed is a surface water drainage unit approximately 137 square miles in areal extent, discharging to the Milwaukee River in the City of Milwaukee about 0.9 mile upstream from where the Milwaukee River enters Lake Michigan. The Menomonee River watershed is wholly contained within the seven-county Southeastern Wisconsin Planning Region, is the fifth largest of the 11 distinct watersheds located wholly or partly within the Region, and comprises 5 percent of the total land and water area of the Region. The Menomonee River has its source in a large woodland-wetland area in the northeastern corner of the Village of Germantown, Washington County. As it flows in a generally southerly and easterly direction from its headwater areas to its confluence with the Milwaukee River near Lake Michigan, the Menomonee River passes through a wide spectrum of land uses ranging from essentially natural woodland-wetland areas through agricultural and suburban residential areas to intensely developed residential, commercial, and industrial areas.

Superimposed upon the natural meandering watershed boundary is a generally rectilinear pattern of local political boundaries. The watershed occupies portions of four of the seven counties comprising the Southeastern Wisconsin Region—Milwaukee, Ozaukee, Washington, and Waukesha—and portions or all of seven cities, six villages, and four towns. Four soil and water conservation districts have jurisdiction over portions of the watershed. In addition, certain other special-purpose districts have important responsibilities for water resource management within the watershed, including the Metropolitan Sewerage District of the County of Milwaukee, two sanitary districts, and one legally established farm drainage district.

Superimposed on these local, general, and special-purpose units of government are the state and federal governments, certain agencies of which also have important responsibilities for resource conservation and management. These include the Wisconsin Department of Natural Resources; the University of Wisconsin Extension Service; the State Soil Conservation Board; the U.S. Department of Agriculture, Soil Conservation Service; the U.S. Department of the Interior, Geological Survey; the U.S. Environmental Protection Agency; and the U.S. Department of the Army, Corps of Engineers.

Population and Economic Activity

The 1970 population of the watershed was estimated at 348,165 persons, or 20 percent of the total resident population of the Region. The greatest proportion of the watershed population—80 percent—resides in Milwaukee County which comprises about 40 percent of the watershed area. Since 1900, the growth rate of the population of the Menomonee River watershed generally has exceeded those of the Region, the State and the Nation. The population of the watershed is expected to increase to about 388,000 persons by the year 2000, or by an additional 12 percent, over the 30-year period.

Employment within the watershed in 1972 totaled about 170,600 jobs and is expected to increase to about 218,800 jobs by the year 2000, an increase of about 48,200 jobs, or 28 percent, over the 28-year period. The largest concentration of industry within the watershed lies in the City of Milwaukee, where 44 of the 69 industrial firms within the watershed, employing 150 or more persons each, are located. Most of the resident labor force of the watershed finds employment in the major industrial centers of the Milwaukee urbanized area, including such centers located in the highly urbanized areas of the lower watershed. Most of the agricultural activity remaining within the watershed is located in Washington and Ozaukee Counties in the basin.

Land Use

Land within the watershed is undergoing a rapid transition from rural to urban use in response to increasing population and economic activity levels. Urbanization is particularly rapid in the middle and upper reaches of the watershed. In the 20-year period from 1950 to 1970, a 42 percent increase in the population of the watershed was accompanied by a 156 percent increase in the amount of land devoted to urban use within the watershed and by a marked decrease in the density of the developed portions of the watershed from 8,400 persons per square mile to about 4,800 persons per square mile. This diffusion of low-density urban development within the watershed is a major factor contributing to a number of the serious environmental and developmental problems existing within the watershed.

As of 1970, 73 square miles, or 53 percent of the total area of the watershed, were in urban as opposed to rural land uses. The dominant urban land use in the watershed is residential, a use that in 1970 encompassed 34 square miles, or 25 percent, of the watershed area. The larger, contiguous rural areas that do remain are located in the Washington and Ozaukee Counties portions of the watershed. The Milwaukee and Waukesha portions of the basin are almost totally urbanized. About two-thirds of the 47 percent of the watershed broadly categorized as still rural in 1970 was used for agricultural and related purposes while the remaining one-third was classified as other open lands, swamps, and water areas. The prime agricultural lands remaining in the watershed total about 14 square miles and are located in the headwater areas of the watershed along the Little Menomonee River.

Continuation of present development trends within the watershed may be expected to result in an increase in urban land use, from approximately 73 square miles in 1970 to approximately 90 square miles by 2000, an increase of 23 percent. Residential land use may be expected to increase from 34 square miles in 1970 to 43 square miles by 2000, an increase of 26 percent. All other urban land uses may be expected to increase from 39 square miles to 47 square miles over this same period of time, an increase of 21 percent. This demand for urban land will have to be satisfied primarily by converting agricultural lands, woodlands, and wetlands, which collectively may be expected to decline by about 17 square miles, a decrease of about 28 percent. If existing trends continue, much of this new urban development will not be related sensibly to the natural resource base—the soils, the streams and associated floodlands and shorelands, the woodlands, the wetlands, and the wildlife habitat areas of the watershed—nor to existing public utility systems and service areas.

Public Utility Service and Transportation Facilities

The public utility base of the watershed is composed of its sanitary sewerage systems, water supply systems, electric power service, and gas service. Adequate supplies of both electric power and natural gas have been available within the watershed, with the electric and gas utilities being ready to extend on demand both electric and gas service to any part of the watershed. Although this historic utility extension policy has not as yet been changed, there is some indication that the privately owned utilities concerned may change this policy in the future. Expansion of sanitary sewerage and water supply systems have not fully kept pace with the rapid urbanization of the Menomonee River watershed. As a result, there are significant concentrations of unsewered urban development in the watershed, primarily in the City of Brookfield and the Village of Menomonee Falls.

About 61 square miles, or 84 percent of the urbanized area of the watershed and 45 percent of the total watershed area, and approximately 311,500 people, or about 89 percent of the total watershed population, are served by public sanitary sewerage facilities. The largest concentrations of urban development within the watershed not served by public water supply systems are located in the City of Brookfield and the Villages of Elm Grove and Menomonee Falls. Approximately 56 square miles, or 77 percent of the urbanized area of the watershed, 41 percent of the total watershed area, and 85 percent of the total watershed population, are served by public water supply systems. The four public water utilities located in the Milwaukee County portion of the watershed utilize Lake Michigan as a source, whereas all of the four public utilities in the Waukesha and Washington County parts of the watershed draw on the groundwater reservoir.

Detailed operational soil surveys are available for 85 percent of the watershed. These surveys indicate that approximately 23 square miles, or about 20 percent of that portion of the watershed for which soils data are available, are covered by soils which are poorly suited for urban development of any kind. Approximately 51 square miles, or about 44 percent of that portion of the watershed for which soils data are available, are covered by soils which are poorly suited for residential development without public sanitary sewer service on lots of one acre or more in area; and about 93 square miles, or about 81 percent of that portion of the watershed for which soils data are available, are covered by soils poorly suited for urban development without public sanitary sewer service on lots of less than one acre in size.

The watershed is well served by an extensive all-weather, high-speed highway system which includes about 35 miles of freeway. Partly because of that highway system, strong urbanization pressures may be expected to be exerted on the remaining rural headwater areas of the watershed since these areas are located within a 30-minute driving time of the major employment, shopping, and service centers of the Milwaukee area. Three types of bus service are available in the watershed: urban mass transit, intercity bus service, and suburban mass transit. Urban mass transit service is provided to most of the intensely urbanized portion of the watershed within Milwaukee County. Railroad service in the watershed is limited to freight hauling, except for scheduled Amtrak passenger service over the lines of the Chicago, Milwaukee, St. Paul, and Pacific Railroad (Milwaukee Road) between the Union Station in Milwaukee—which is the only stop in the watershed—and Chicago to the south and Minneapolis-St. Paul to the west.

Climate

The Menomonee River watershed is subject to a semihumid continental type climate and is characterized by the seasonal extremes in weather common to its latitude and interior position on the North American continent. A continuous pattern of distinct weather changes occurring at two-or-three-day intervals is superimposed on the seasonal pattern.

Air temperatures within the watershed generally lag about one month behind the summer and winter solstices, resulting in July being the warmest month and January the coldest. Air temperatures in the watershed range from a daily average of about 20°F in January to a 72°F daily average in July. Watershed temperature extremes have ranged from a low of about -30°F to a high of approximately 108°F. The growing season averages about 150 days within the watershed and extends from about the first half of May to the first half of October. Frost normally penetrates the soils of the watershed to depth of six or more inches during January, February, and the first half of March. Depths in excess of four feet have been observed in southeastern Wisconsin.

The average annual precipitation within the watershed is 29.1 inches, but has varied from a recorded low of about 17 inches in 1901 to a recorded high of approximately 50 inches in 1876. Average monthly precipitation ranges from a low of 0.97 inches in February to a high of 3.61 inches in July. Snowfall averages about 42 inches per year and, when converted to its water equivalent, accounts for approximately 15 percent of the average annual precipitation. Snowfall in and near the watershed has ranged from a recorded minimum cumulative seasonal snowfall of 5.0 inches during the 1901-1902 winter to a recorded maximum of about 109 inches for the 1885-1886 season. About 94 percent of the annual snowfall occurs in the four months of December, January, February, and March. On an annual basis, approximately three-fourths of the precipitation that falls on the Menomonee River watershed is returned to the atmosphere from the basin by evapotranspiration with the remaining one-quarter appearing as streamflow at the watershed outlet.

Prevailing winds follow a clockwise pattern over the seasons of the year, being generally northwesterly in the late fall and in winter, northeasterly in the spring, and southwesterly in the summer and early fall. Daylight hours in the basin range from a minimum of about nine hours on about December 22 to a maximum of about 15 hours on about June 21. During the summer months, about one-third of the days may be expected to be categorized as clear, one-third as partly cloudy, and one-third as cloudy. More sky cover occurs in the winter when over one-half of the days are classified as cloudy with the remainder being approximately equally divided between partly cloudy and clear.

Physiography and Geology

The Menomonee River watershed is an irregularly shaped drainage basin, with its major axis lying in an approximately north and south direction. The watershed has a total area of approximately 137 square miles, with a length of approximately 23 miles and a width varying from about five miles in the middle portions of the watershed to about 12 miles in the lower portions of the watershed.

Watershed topography and physiographic features have been largely determined by the underlying bedrock and overlying glacial deposits. The Niagara cuesta, on which the watershed lies, is a gently eastward sloping bedrock surface. The topography of the watershed is asymmetrical with the eastern border of the watershed being generally lower—by about 150 to 300 feet—than the western border. The northwestern portion of the watershed lies close to the Kettle Moraine, and its topography is characterized by rolling ground moraine similar to, but more subdued than, the kettle and kame topography of the Kettle Moraine. Surface elevations within the watershed range from a high of approximately 1,120 feet above mean sea level in the northwestern area of the watershed to a low of approximately 580 feet above mean sea level in the Menomonee River Industrial Valley, a maximum relief of about 540 feet.

A major subcontinental divide separating the Mississippi River basin from the Great Lakes-St. Lawrence River basin forms much of the western boundary of the Menomonee River watershed. The stream system of the watershed itself discharges to Lake Michigan. The surface drainage pattern of the watershed is diverse with respect to channel shape and slope, the degree of stream sinuosity, and floodland shape and width. The heterogenous character of the surface drainage system is due partly to the natural effects of glacial drift and partly to the extensive channel modifications evident in the lower watershed. Major tributaries to the Menomonee River include the Little Menomonee River, Underwood Creek, and Honey Creek.

The bedrock underlying the watershed consists of a complex system of layers of rock formations in which the type and extent of the various formations are determined primarily by the environments in which the sediments forming the rock layers were deposited. The bedrock formations underlying the watershed slope gently downward toward the east and consist in ascending order, of predominantly crystalline rocks of the Pre-Cambrian Era, Cambrian through Devonian Period sedimentary rocks of the Paleozoic Era, and unconsolidated surficial deposits. Sand and gravel, dolomite building stone and crushed aggregate, and organic material are the three principal mineral and organic resources in the watershed that have any significant commercial value.

Woodlands and Wetlands

The extensive vegetation, primarily hardwood forest, that once covered the entire Menomonee River watershed has been reduced to only scattered remnants of woodlands and wetlands, principally as a result of man's activities. Woodlands were defined for the purposes of the study as lands of at least 10 acres in area covered by a dense, concentrated stand of trees and associated undergrowth. Wetlands were defined as those lands at least 10 acres in area wholly or partially covered with wet and spongy organic soils and with plants that grow in water or wet habitats. Wetlands also are characterized as being covered with shallow standing water, being intermittently inundated or having a high water table.

A 1973 Wisconsin Department of Natural Resources inventory of all remaining woodland-wetland areas not permanently protected by public ownership indicated the existence of 22 such areas covering a total area of only 4.3 square miles. Ten of the 22 sites may be categorized as woodlands while the remaining 12 sites may be categorized as wetlands. Ranging in size from about 10 to approximately 540 acres, these sites encompass only 3.2 percent of the total area of the watershed. About two-thirds of the remaining woodlands were classified under the study as in the lowest quality category due to a high degree of disturbance and the absence of desirable diversity. One high quality site—Bishops Woods in the City of Brookfield—was identified at the time of the survey but has since been significantly diminished in size and value as a result of the development of an office park within the woods. Even if the woodland portions of publicly and privately owned park, outdoor recreation, and related open space sites are considered in conjunction with the unprotected woodlands in the watershed, the remaining woodlands cover an area of approximately 5.3 square miles, or 3.8 percent of the total area of the watershed.

Although only remnants exist of the extensive woodland-wetland areas that once covered most of the watershed, those remnants have the potential to contribute significantly to the maintenance of the overall quality of life in the watershed. These woodland-wetland areas have scenic attributes, serve as visual and acoustic shields, are the focal point of wildlife productivity, provide desirable range for wildlife, help to maintain the quality of the surface waters, have the potential to fulfill education and research functions, and can provide an excellent setting for certain outdoor recreational activities.

The watershed portion of the Milwaukee County park system provides an excellent example of how continuous portions of riverine area woodlands and wetlands can be protected by public acquisition so as to fulfill many of the above functions. Inasmuch as the remaining woodlands and wetlands in the Ozaukee, Washington, and Waukesha Counties portion of the watershed are concentrated in riverine areas, multifunction parkways and natural areas could be acquired and carefully developed in those portions of the watershed.

Fish and Wildlife

Historic and recent information indicate a general deterioration in the quality of the sport fishery in the watershed stream system. A 1973 fish shocking survey conducted under the watershed study at 24 locations distributed throughout the stream system revealed the presence of almost eight times as many fish that are very tolerant or tolerant to pollution as there were pollution-intolerant fish. Of the 23 species of fish captured during the instream fish shocking survey, only five species were considered to be of sport fishing value. The dominance of the very tolerant and tolerant fish and the relatively small number of sport fish species, is indicative of the surface water quality conditions that exist throughout the watershed.

Although the existing fishery is of little value, a valuable sport fishery could be naturally maintained in some of the stream system of the watershed if water quality conditions were improved. The naturally self-sustaining fishery could be supplemented with a stocked anadromous sport fishery in which large Lake Michigan fish including coho salmon, chinook salmon, Atlantic salmon, brook trout, brown trout, and rainbow trout would move up the Menomonee River and some of its major tributaries during their spawning seasons.

One hundred distinct wildlife habitat areas still exist within the watershed. These wildlife habitat areas encompass a total area of about 17.5 square miles, or 13 percent of the total area of the watershed. Most of the areas are relatively small, with 84 being 160 acres or less in extent. Only three high quality wildlife habitats remain in the watershed—the Tamarack Swamp and Held Maple Woods in the Village of Menomonee Falls and the Germantown Swamp in the Northeast corner of the Village of Germantown. These three high quality wildlife habitat sites, which encompass a total area of approximately 1,040 acres, and most of the 22 good quality sites, which cover a total area of about 2,880 acres, all are concentrated in the upper, primarily still rural portions of the watershed.

A variety of amphibians and reptiles exists in the watershed, but many species are being dispersed and reduced in number as a result of urbanization. A surprisingly large number and variety of birds—over 230 species—are found in the watershed either as migrants or as breeders, including game birds such as the pheasant and Hungarian partridge; waterfowl such as the mallard and teal; and songbirds such as cardinals and warblers. Less desirable birds found in the watershed include the English sparrow and pigeons, both of which thrive in the urban areas and replace those species less tolerant to urban conditions.

A variety of mammals exists within the watershed and ranges in size from the northern whitetailed deer to the pygmy shrew. Urbanization has diminished and continues to diminish the quantity and quality of much of the mammal population of the watershed because of the demanding habitat requirements of most species. Certain mammals such as the cottontail rabbit, the gray squirrel, and bats are compatible with an urban environment, provided some semblance of natural habitat remains.

The wildlife that remains within the Menomonee River watershed, although significantly reduced in quantity and quality relative to presettlement conditions, also has the potential to contribute significantly to the overall quality of life in the watershed if the key remaining habitat areas are protected and properly managed. The Milwaukee County Park System, with its linear and continuous parkways, provides an example of how wildlife habitat can be preserved in an urban area. This parkway system provides continuous range, linking the urban and rural areas of the watershed; contains a variety of wildlife; and is readily accessible to urban residents of the lower portions of the watershed. Opportunities for the creation of similar linear wild life reserves still remain in the riverine areas of the Ozaukee, Washington, and Waukesha Counties portions of the watershed.

Ecologic Units

The Menomonee River watershed was divided into eight ecologic units to permit an integrated analysis of the watershed natural resource base and a better understanding of its potential for maintaining and improving environmental quality. These ecologic units were selected to be relatively homogeneous with respect to such elements of the natural resource base as surface water quality, the extent and quality of the remaining woodlands, wetlands, wildlife, and wildlife habitat. In addition, the ecologic units also were selected to be generally homogeneous with respect to land use and other aspects of man's influence on the natural resource base.

This unit-by-unit analysis clearly indicates that the quantity, quality, and diversity of wildlife habitat, fish life, and woodland-wetland areas declines in a generally northwest to southeast direction across the basin: that is, the loss of natural resource values of the ecologic units is directly correlated with the degree of urbanization and the intensity of man's activity. Paradoxically, it was the natural values of the lower portion of the Menomonee River watershed and the adjacent Milwaukee and Kinnickinnic River watersheds that attracted the early settlers who initiated the urbanization process. This example of a common pattern of exploitation emphasizes the importance of selectively preserving and enhancing the dwindling natural resources that still exist in the basin.

Existing and Potential Park, Outdoor Recreation and Related Open Space Sites

A total of 243 existing park, outdoor recreation, and related open space sites lies within the watershed, encompassing a combined area of 6,138 acres, or about 7 percent of the total area of the watershed. Of this total, 177 sites, occupying a combined area of 5,460 acres, or 89 percent of the total acreage, are in public ownership. The remaining 66 sites, encompassing a combined area of 678 acres, or 11 percent of the total acreage, are in private ownership. Of the 5,460 acres of park, outdoor recreation, and related open space sites in public ownership, 4,200 acres, or 77 percent, are owned by Milwaukee County, and most of that consists of parkway lands along the Menomonee and Little Menomonee Rivers and Underwood and Honey Creeks. Other publicly owned acreage, small in comparison to the Milwaukee County total, consists mainly of intensively used park and active outdoor recreation areas within the urban centers of the watershed.

A total of 18 potential outdoor recreation and related open space sites have been identified in the watershed—one in Milwaukee County, three in Ozaukee County, five in Washington County, and nine in Waukesha County. High value ratings were assigned to three of these sites, while 10 of the sites were determined to be of medium value and five of low value. The three high value sites were Bishops Woods in the City of Brookfield before its recent partial development for commercial use, the Tamarack Swamp in the Village of Menomonee Falls, and a site along the Menomonee River in the Village of Germantown northeast of the USH 41-STH 167 interchange. Fourteen of the 18 potential recreation and related open space sites are in the smallest size category-less than 150 acres. Only one site—the Tamarack Swamp in the Village of Menomonee Falls—is in the largest size category, greater than 1,000 acres. The limited number and the small size of the potential sites reflect the urban and urbanizing characteristics of the watershed.

The watershed study included an analysis of outdoor recreational demand exerted by watershed residents and the ability of the existing and potential recreational lands within the watershed to meet those demands. The availability of facilities for, and the participation in, outdoor recreational activities is an important index of the overall quality of life enjoyed by the residents of an urban and urbanizing area like the Menomonee River watershed.

A 1970 outdoor recreational activity survey conducted by the Wisconsin Department of Natural Resources was used as the basis for preparing estimates of existing and probable future outdoor recreational activity demand by watershed residents. Seventeen categories of major outdoor recreational activities were utilized, and the demand for each was expressed in terms of participant-days on a peak weekend day during the season appropriate for the particular activity. The 1970 outdoor recreational activity demand in the Menomonee River watershed was estimated to total about 126,000 participant-days per peak seasonal weekend day. The four most popular outdoor recreational activities were swimming, picnicking, fishing, and target shooting which together account for 56 percent of the demand. Water-based activities account for 43 percent of the outdoor recreational activity demand with the remainder being categorized as land-based. The year 2000 outdoor recreational activity demand was forecast to be about 25 percent greater than the 1970 demand, with the relative distribution among the 17 categories of major outdoor recreational activities remaining essentially unchanged.

Area-use standards were applied to the outdoor recreational activity demand to determine the amount of recreational land required to meet the existing and probable future demands of watershed residents for the five recreational activities requiring intensive site development: picnicking, swimming, snow skiing, golfing, and camping. A comparison of the required land to the existing lands indicated that there are sufficient swimming and picnicking lands and facilities and golf courses to meet the existing and probable future demand for these three activities through the year 2000. However, inasmuch as the existing swimming and picnicking areas and golf courses are currently concentrated in the urban areas of the watershed, it may be desirable to develop additional swimming and picnicking sites and golf courses in the northern portions of the basin to facilitate ease of access by the residents of newly urbanizing areas. Inasmuch as there are no campgrounds in the watershed and little potential for developing quality camping areas with the capacity to satisfy the demand. Residents of the Menomonee River watershed and surrounding urban and urbanizing areas will have to travel to other, more rural parts of the Region and the State to satisfy their camping demands.

The Menomonee River watershed also is deficient in snow skiing facilities, but enough potential sites exist for development of the necessary additional facilities by either private interests or public entities. It can be assumed that demands for most of the remaining 12 outdoor recreation activities can be satisfied either on recreational backup lands or on public rights-of-way. Three exceptions are motor boating, water skiing, and target shooting. The surface water resources of the basin are not, from a strictly physical standpoint, capable of supporting motor boating and water skiing whereas the urban and urbanizing nature of the watershed does not lend itself to the pursuit of outdoor target shooting. In addition, although a sport fishery could be developed on some portions of the watershed stream system, it is unlikely that such a fishery would satisfy the total fishing demand of watershed residents. Thus some of the demand will have to continue to be met outside of the watershed.

Environmental Corridors

One of the most important tasks completed as part of the regional land use planning effort was the identification and delineation of those areas of the Region in which concentrations of recreational, aesthetic, ecological, and cultural resources occur and which, therefore, should be preserved and protected. Such areas, by definitions, contain several important elements of the underlying and supporting natural resource base, including the streams and watercourses and associated shorelands and floodlands; woodlands; wetlands; wildlife habitat areas, wet or poorly drained soils and organic soils; areas containing rough topography and significant geological formations and sites of historic or cultural value; and the best remaining potential park and related open-space sites. The delineation of these natural resource and natural resource-related elements results in an essentially lineal pattern of narrow, elongated areas which have been termed "environmental corridors" by the Commission. The preservation of these corridors in an essentially natural state, or in park or related open-space uses—including limited agricultural and large, very low density, estate-type residential uses—is essential to maintaining the overall quality of the environment within the watershed and to protecting its natural beauty.

The primary environmental corridors in the Menomonee River watershed, as delineated by the Commission during preparation of the initial regional land use plan, occupied approximately 18 gross square miles, or about 13 percent of the total area of the watershed. The gross primary environmental corridor area is defined as including all land uses, both urban and rural, whereas the net primary environmental corridor area is defined as the gross corridor acreage minus the noncompatible urban land use acreages in the corridor. Net corridor areas consist of recreational land uses, agricultural and related land uses, water, wetlands and woodlands, and other open space land uses. Net primary corridor areas in the watershed total nearly 16.6 square miles, or about 12 percent of the watershed area.

It is important to note that the primary environmental corridors contain almost all of the remaining high value wildlife habitat areas and woodland-wetlands within the watershed, in addition to almost all of the streams and associated shorelands and floodlands. These corridors also contain all three of the best remaining potential park sites. The primary environmental corridors, in effect, encompass a composite of the best remaining individual elements of the natural resources base of the Menomonee River watershed.

Water Law

Water law is not a simple or fixed body of law. It has historical roots which reach back beyond the common law. Three principal divisions of water law may be identified: riparian and public rights law, groundwater law, and diffuse surface water law. Riparian and public rights law applies to the use of surface water occurring in natural rivers, streams, lakes, and ponds. Groundwater law applies to the use of water occurring in the saturated zone below the earth's surface. Diffuse surface water law applies to water drainage over the surface of the land. Water law in Wisconsin has probably never been in a greater state of change than it is at present. In 1974 alone, the Wisconsin Supreme Court in landmark cases expressly overruled the historic common law doctrine with respect to both groundwater law and diffuse surface water law, finding that these historic doctrines were no longer applicable to modern water resource problems and conflicts.

With the passage of the Federal Water Pollution Control Act Amendments of 1972, the U.S. Congress set in motion a series of actions which will have many ramifications for water quality management within the Region and the Menomonee River watershed. Water use objectives and supporting water quality standards are now required for all navigable waters in the United States. It is a national goal to eliminate the discharge of pollutants into the navigable waters of the United States by 1985. To meet this goal, the Act requires the enactment of specific effluent limitations for all point sources of water pollution. The Act also establishes a pollutant discharge permit system to issue permits for the discharge of any pollutants subject to conditions that the discharge will meet all applicable effluent limitations and contribute toward achieving the water use objectives and supporting water quality standards.

Responsibility for water quality management in Wisconsin is centered in the Wisconsin Department of Natural Resources. The Department is given authority to prepare long-range water resources plans, to establish water use objectives and supporting water quality standards applicable to all waters of the state, to establish a pollutant discharge permit system, and to issue pollution abatement orders.

In addition to the broad grant of authority to general purpose units of local government to regulate in the interests of health, safety, and welfare, the Wisconsin Statutes currently provide for the creation of five types of special-purpose units of government through which water pollution can be abated and water quality protected. These special units of government are the Metropolitan Sewerage District of the County of Milwaukee, other metropolitan sewerage districts, utility districts, joint sewerage systems, and cooperative action by contract. The Metropolitan Sewerage District of the County of Milwaukee has authority extending over the entire Menomonee River watershed and represents for all practical purposes the single entity responsible for the conveyance and treatment of sanitary sewage in the Menomonee River watershed. The cooperative action by contract power has been utilized in the Menomonee River watershed by the City of Brookfield and the Villages of Elm Grove and Menomonee Falls to provide for the construction, operation, and maintenance of intercommunity trunk sewers.

The effective abatement of flooding can only be achieved by a comprehensive approach to the problem. As urbanization proceeds within a watershed, it becomes increasingly necessary to develop an integrated program of land regulation of the floodlands of the entire watershed. The Commission has recommended that the natural floodlands of a river or stream be specifically defined as those lands inundated by a flood having a recurrence interval of 100 years. Under ideal regulatory conditions, the entire natural floodlands would be maintained in an open, essentially natural state, and would not be filled and utilized for incompatible land uses. The enactment of sound floodland regulations is required under the state floodplain management program and for municipal participation in the federal flood insurance program. A Governor's Executive Order designed to promote a unified state policy of floodland management requires that all state agencies appropriately take into account flood hazards and local floodland regulation in state agency actions.

Flood control facilities may be constructed in the Menomonee River watershed either through cooperative action by contract of the local municipalities or by the use of special purpose districts. Such districts include the Metropolitan Sewerage District of the County of Milwaukee, which has historically carried out extensive drainage course improvements in the Menomonee River watershed; flood control boards; and soil and water conservation districts.

Inventories were conducted under the Menomonee River watershed study for state water regulatory permits issued in the watershed under Chapters 30 and 31 of the Wisconsin Statutes, as well as for permits for high capacity wells issued under Chapter 144 of the Wisconsin Statutes.

In addition, inventories were conducted for state effluent discharge permits, state pollution abatement orders, and federal waste outfall permits.

Surface and Ground Water Hydrology and Hydraulics

Surface water resources, consisting primarily of streams and associated floodlands, provide the singularly most important feature of the landscape within the Menomonee River watershed and serve to enhance all proximate land uses. There are approximately 69 lineal miles of perennial streams and watercourses within the watershed. Inasmuch as there are no major lakes—50 acres or more in size—in the watershed, the surface water resources consist essentially of the stream system. The groundwater resources of the watershed are closely interrelated with the surface water resources, sustaining the wetlands and providing the base flows of streams as well as providing important sources of supply for municipal, industrial, commercial, and domestic water users.

Quantitative knowledge of the complex hydrologic cycle as it affects the watershed is necessary to assess the availability of surface and ground water for various uses and to improve the management potential of water during times of flooding or drought. The quantitative relationships between inflow and outflow, termed the hydrologic budget, were determined for the watershed. Precipitation is the primary source of water to the watershed and averages 29.1 inches annually. Surface water runoff and evapotranspiration losses constitute the primary outflow from the basin. The average annual runoff approximates 8.2 inches, while the annual evapotranspiration loss totals about 20.9 inches.

The Menomonee River watershed may be considered as a composite of 14 subwatersheds ranging in size from the 3.3-square-mile Little Menomonee Creek subwatershed to the 29.1-square-mile Upper Menomonee River subwatershed. Hydrologic-hydraulic information including soils, land use, channel slopes, hydraulic structure, and channel modification data was inventoried and analyzed for each of the subwatersheds. Marked variations in this subwatershed information reveal that the Menomonee River watershed is a microcosm of the seven-county Region containing the full spectrum of possible land uses, land use activities, and attendant hydrologic-hydraulic characteristics and problems.

Although stream flow records available for the Menomonee River stream system cover only slightly more than a decade, these records do reveal key characteristics of the hydrologic-hydraulic system of the watershed. Major flood discharges in the watershed tend to result from rainfall events, as opposed to either snowmelt or combined rainfall-snowmelt events which have historically produced the major floods in the larger watersheds of southeastern Wisconsin. As a consequence, peak floods are distributed throughout the late winter, spring, and summer seasons rather than concentrated in the late winter and early spring as is true in the larger watersheds. As a result of extensive urbanization and the attendant large extent of impervious surface and extensive storm water drainage systems and channelization works, the response of the watershed to large rainfall events is rapid in that peak discharges generally occur near the lower end of the watershed from within a fraction of a day to two days after the initiation of such an event.

Mean annual streamflow as recorded at the Wauwatosa gage for water years 1961 through 1973 has ranged from a low in 1963 of 24.0 cfs, or 2.67 inches of runoff, to a high in 1973 of 126 cfs, or 13.93 inches of runoff, while the average annual streamflow is 74.2 cfs, or 8.19 inches of runoff. Prolonged periods of high streamflow occur principally in March and April with these months exhibiting average runoff quantities which account for almost half the average annual runoff from the watershed.

Approximately 72 lineal miles of the watershed stream system were selected for development of detailed flood hazard information, including discharge-frequency relationships, flood stage profiles, and mapped areas of inundation for selected flood recurrence intervals. Channel slopes throughout these reaches are irregular with steeper slopes near the headwater areas and milder slopes in the middle and lower reaches of each stream. The steepest channel slopes in the watershed approximate 100 feet per mile and occur along the Menomonee River in the Village of Menomonee Falls. The median channel slope in the stream system is about 15 feet per mile.

Channel modifications—or channelization as it is commonly called—usually includes one or more of the following changes to the natural stream channel: straightening, deepening, widening, placement of concrete invert and sidewalls, rip rap, and reconstruction of selected bridges and culverts. Compared to most of the other watersheds in the Region, a rather large portion of the stream system of the Menomonee River watershed has been modified for flood control or agricultural drainage purposes. Of the 72 miles of stream system selected for development of detailed flood hazard data, 48.2 miles, or 67 percent, are known to have undergone some type of man-made channel modification. Modification of this nature includes about 29.9 miles of minor channel work, 15.8 miles of major channelization, and 2.5 miles of conduit. Although channel modifications can provide local flood relief, there is a potential for adverse downstream hydraulic effects in that channelization reduces the floodwater storage capability of the modified reaches, thereby generally giving rise to downstream flood hydrographs that have, relative to prechannelization conditions, shorter bases and higher peaks.

Depending on the size of the waterway opening and the characteristics of the approaches, bridges and culverts can be important elements in the hydraulics of a watershed. The 72 miles of stream system selected for simulation modeling are crossed by 249 bridges and culverts, of which 170 were determined to be hydraulically significant. Detailed data were obtained for these hydraulically significant structures, including measurement of the waterway opening, determination of channel bottom elevations, and construction of a profile from one side of the floodplain to the other. A network of vertical survey control stations referenced to mean sea level datum was established on all 170 hydraulically significant bridges and culverts. Descriptive data similar to that obtained for the bridges and culverts were obtained for two hydraulically significant dams—the former mill dam in the Village of Menomonee Falls and The Falk Corporation dam in the City of Milwaukee, both on the Menomonee River—and for 18 channel drop structures. An estimated 933 floodland cross-sections at an average spacing of 500 feet were prepared to represent accurately the configuration of the channel and its floodplain between bridges, culverts, dams, and drop structures.

The Menomonee River watershed is richly endowed with groundwater resources. Three groundwater aquifers underlie the watershed: the unconsolidated sand and gravel deposits of the glacial drift; the dolomite aquifer, consisting of dolomite strata of the underlying and interconnected bedrock; and the sandstone aquifer, consisting mainly of sandstone and dolomite strata.

The movement of groundwater through the three aquifers beneath the Menomonee River watershed is governed by the spatial variation in the magnitude of total hydraulic head which may be depicted in the form of potentiometric maps for both the deep sandstone aquifer and the combination of the shallow dolomite and sand and gravel aquifers. Groundwater in the deep sandstone aquifer beneath the aquifer moves in a generally southerly, southeasterly direction, whereas flow in the dolomite and sand and gravel aquifers tends to be more varied in that it is influenced by the location of wells and low-lying natural discharge areas. Well data were used to develop values for important hydraulic parameters of the groundwater aquifers such as hydraulic conductivity, transmissivity, the storage coefficient, and specific capacity.

The sandstone aquifer comprises the deepest of the three aquifer systems. Wells tapping this aquifer are sometimes more than 2,000 feet deep and are, therefore, relatively expensive to drill. The surface of the sandstone aquifer is located approximately 700 to 800 feet below the surface of the watershed land surface, and the thickness of the aquifer ranges from about 700 feet in the northwestern portion of the watershed to more than 1,500 feet in the southeastern portion of the basin. More than about 14 million acre-feet of water are in storage in the watershed portion of the sandstone aquifer, a quantity of water that would be sufficient to cover the entire watershed land surface to a depth of 160 feet. This aquifer, except for minor leakage and connection to the natural recharge area, is hydraulically separated from the shallower aquifer systems by an overlying, nearly impermeable shale formation. This separation makes the deep aquifer less susceptible to man-made pollution. Recharge of the deep sandstone aquifer is by percolation in the recharge areas located west of the watershed. The rate of withdrawal of water from the sandstone aquifer has for some time exceeded the rate of recharge, and still does so, and this has resulted in potentiometric surface declines in excess of 400 feet below the levels that existed in about 1880 when the aquifer was first tapped by wells.

The dolomite aquifer, one of the two "shallow" aquifers, is overlain by up to about 250 feet of unconsolidated glacial drift and alluvial deposits. Dolomite aquifer thickness is quite variable, ranging from a minimum of about 100 feet in the southeastern portion of the basin and in parts of the Village of Menomonee Falls to a maximum of 450 feet in the Village of Germantown. More than 1.25 million acre-feet of water are in storage in the watershed portion of the dolomite aquifer, a quantity of water that would be sufficient to cover the entire watershed land surface to a depth of 14 feet. Recharge is by leakage from the overlying glacial deposits.

The sand and gravel aquifer, the other "shallow" aquifer, is up to 250 feet thick in some portions of the watershed while in other areas this aquifer is present in the form of thin lenses of unconsolidated material or is absent, in which case the underlying dolomite aquifer is exposed at the land surface. Compared to the dolomite and sandstone aquifers, the volume of water stored in the sand and gravel aquifer is negligible. Direct infiltration of precipitation is the major source of recharge to the sand and gravel aquifer. Groundwater pumpage from the shallow aquifer may affect local groundwater movement and runoff; and shallow wells located near streams or wetlands may directly or indirectly affect streamflow and the stages of wetlands. About 1.40 million acre-feet of water are in storage in the watershed portion of the sand and gravel aquifer, a quantity of water that would be sufficient to cover the entire watershed land surface to a depth of 16 feet.

Water Resource Simulation Model

A quantitative analysis of watershed surface water hydrology, hydraulics, and water quality under existing and alternative future conditions is a fundamental requirement of any comprehensive watershed planning effort. The ideal way to investigate the behavior of the hydrologic-hydraulic-water quality system of a watershed would be to make direct measurements of the phenomena involved. Such a direct approach is not generally feasible because of the extremely high costs, the improbability of the occurrence of critical events, and the inability to evaluate the impacts of possible future land and stream conditions.

Hydrologic-hydraulic-water quality-flood economics simulation, accomplished with a set of interrelated digital computer programs is an effective way to conduct the quantitative analysis required for watershed planning. Such a water resource simulation model was developed for and used in the Menomonee River watershed planning program. The various submodels comprising the model were selected from existing computer programs or were developed by the Commission staff so that the composite model would meet the watershed study needs. The Water Resource Simulation Model developed for and used in the Menomonee River watershed planning program consists of the following five submodels: the Hydrologic Submodel, Hydraulic Submodel 1, Hydraulic Submodel 2, the Water Quality Submodel, and the Flood Economics Submodel.

The principal function of the Hydrologic Submodel is to determine the volume and temporal distribution of runoff from the land to the stream system. Meteorological data and land data constitute the two principal types of input for operation of the Hydrologic Submodel. The key output from the Submodel consists of a continuous series of runoff quantities for each land segment in the watershed. The function of Hydraulic Submodel 1 is to accept as input the runoff from the land surface as produced by the Hydrologic Submodel, to aggregate it, and to route it through the system thereby producing a continuous series of discharge values at predetermined locations along the surface water system of the watershed. Hydraulic Submodel 2 computes flood stages attendant to flood flows of specified recurrence intervals as produced by Hydraulic Submodel 1. The principal output from Hydraulic Submodel 2 consists of flood stage profiles which are used to delineate flood hazard areas and to provide input to the Flood Economics Submodel. The Flood Economics Submodel performs two principal functions: calculation of average annual flood damages to floodland structures—residential and commercial—and computation of the cost of alternative flood control and floodland management measures such as floodproofing of structures, removal of structures, and the construction of earthen dikes, concrete floodwalls, and major channelization works. Output from the model consists of the monetary costs and benefits of each floodland management alternative that is formulated and tested. The Water Quality Submodel simulates the time-varying concentration, or levels, of the following nine water quality indicators at selected points throughout the surface water system: temperature, dissolved oxygen, fecal coliform bacteria, phosphate-phosphorus, total dissolved solids, carbonaceous biochemical oxygen demand, ammonia-nitrogen, nitrate-nitrogen, and nitrite-nitrogen.

The largest single work effort involved in the preparation and application of the Water Resources Simulation Model is data base development. This consists of the acquisition, verification, and coding of the data needed to operate, calibrate, and apply the model. The model data base for the watershed consists of a large, readily accessible computer file of information subdivided into six distinct categories: meteorological data, land data, channel data, riverine area structure data, diffuse source data, and point source data. The data base was assembled using existing Commission data, inventory data collected by the Commission and consultants under the Menomonee River watershed planning program, and data from other sources such as the National Climatic Center.

Many of the algorithms incorporated within the Water Resource Simulation Model are approximations of complex natural phenomena and, therefore, before the model could be used to simulate hypothetical watershed conditions, it was necessary to calibrate the model. Calibration consists of comparing simulation results with historic fact and, if a significant difference occurs, making parameter adjustments so as to tailor the model to the natural and man-made features of the planning region and the watershed. The three types of validation data available for calibration of the Water Resources Simulation Model were streamflow data, flood stage data, and water quality data. The initial calibration of the hydrologic-hydraulic portions of the model were conducted on subwatersheds outside of, but close to, the Menomonee River watershed that were essentially spatially homogeneous with respect to soils, slope, and land use-cover and that had combinations of these three key land characteristics that were similar to those found in land segments of the Menomonee River watershed. The underlying objective was to use the calibration process to determine land parameters for the homogeneous subwatersheds which could in turn be applied to the Menomonee River watershed—a heterogeneous basin containing many different soils, slope, and land use combinations.

Three test areas were selected for the initial calibration runs—the 24.8-square-mile rural and urban Oak Creek subwatershed in Milwaukee County, the 57.9-square-mile rural Root River Canal subwatershed in Racine County, and the 49.6-square-mile rural East Branch of the Milwaukee River subwatershed in Fond du Lac County. These three subwatersheds were used for model calibration because they have streamflow gages and because each has a combination of soils, slope, and land uses-cover similar to portions of the Menomonee River watershed. The iterative calibration process, which consisted essentially of model runs followed by parameter adjustments, was carried out for each of the three subwatersheds until close agreement was achieved between historic and simulated annual runoff volumes, runoff event hydrographs, and discharge-frequency relationships.

After completing calibration of the Hydrologic Submodel and Hydraulic Submodel 1 on the three test subwatersheds, the calibration process was applied to the Menomonee River watershed. The Hydrologic Submodel and Hydraulic Submodels 1 and 2 were successfully calibrated by comparing the simulated discharges to daily streamflows at the U.S. Geological Survey stream gaging station on the Menomonee River gage in Wauwatosa and to peak discharges recorded at three partial record USGS gages and by comparing simulated stages to historic stages available at many locations around the watershed. The Water Quality Submodel was calibrated using data obtained during three 24-hour synoptic water quality surveys conducted under the watershed planning program.

Flood Characteristics and Damage

Flood damage and disruption in the Menomonee River watershed have been largely a consequence of the failure to recognize and account for the relationships which exist between the use of land, both within and outside of the natural floodlands of the watershed, and the flood flow behavior of the stream system of the watershed. A distinction is drawn here between areawide flooding, which is one of the major water resource problem areas addressed in the watershed planning effort, and local storm water drainage problems which are beyond the scope of the Menomonee River watershed planning program. Flood problems are defined as damaging inundation which occurs along well defined rivers and streams as the direct result of water moving out of and away from those rivers and streams, and includes both overland and secondary flooding. In contrast, storm water drainage problems are defined as damaging inundation which occurs when storm water runoff enroute to rivers and streams and other low-lying areas encounters inadequate conveyance or storage facilities and, as a result, causes localized ponding and surcharging of storm and sanitary sewers.

Research of the historic record revealed the occurrence of seven known major floods in the Menomonee River watershed. These major floods, each of which caused significant, widespread damage to property as well as disruption of normal socioeconomic activities, were the floods of March 19, 1897; June 22, 1917; June 23, 1940; March 30, 1960; July 18, 1964; September 18, 1972; and April 21, 1973. The most serious of these floods was also the most recent, the April 21, 1973, event. Based on an analysis of streamflow records available for the Menomonee River at the Wauwatosa gage since October 1961, the July 1964 flood had an instantaneous peak discharge of 6,010 cfs. This flow is estimated to have a recurrence interval of seven years. The instantaneous peak flow for the September 1972 flood was 6,610 cfs, with a nine year recurrence interval, whereas the April 1973 flood peaked at 13,500 cfs and had an estimated recurrence interval of almost 100 years.

In addition to the quantitative data derived from the inventory of historic flooding, several observations emerge regarding the characteristics of flooding in the Menomonee River watershed. There exists, for example, a close correlation between urban growth in the watershed and the severity of flooding which is attributable to the failure to adjust land uses and activities in floodland areas to the natural floodwater conveyance and storage functions of those areas. The historic record also indicates that flooding has caused physical damage to many different types of structures and facilities in a variety of ways and that the disruption attendant to major floods is experienced by many watershed residents—not just those who occupy the floodlands. The inventory of historic flooding reveals that rainfall, as opposed to snowmelt or rainfall-snowmelt combinations, has been the principal cause of major floods. This is particularly significant to the urban and urbanizing Menomonee River watershed because it means that, with the exception of the winter season, major floods can occur any time of the year and, when they do occur, they will be characterized by rapid increases in discharge and stage thereby offering minimal opportunity for warning occupants of riverine areas. The risk to human life inherent in such rapidly rising floods is illustrated by several accounts of near or actual drownings with the threat to human life appearing to be more severe in an urban, as opposed to a rural, watershed.

Flood loss refers to the net effect of historic flooding on the watershed economy and well-being, with the tangible portions of the loss being expressed in monetary terms. Flood risk is the probable damage, expressed either on a per flood event basis or on an average annual basis, that will be incurred as a result of future flooding, with the tangible portion expressed in monetary terms. All flood losses and risks may be classified into one of three categories—direct, indirect, and intangible—or they may be classified by whether the private or public sector incurs the losses or risks. Average annual flood damage risk expressed in monetary terms was selected as the quantitative, uniform means of measuring flood severity in the Menomonee River watershed. The values were derived from damage-probability curves developed for selected reaches under existing, planned, and other alternative land uses. The damage-probability curves were generated by the Flood Economics Submodel of the Water Resource Simulation Model.

Stream Water Quality and Pollution

"Water quality" as applied to surface and ground water resources encompasses the physical, chemical, and biological characteristics of the water. Water is deemed to be polluted when foreign substances caused by or related to human activity are in such a form and concentration so as to render the water unsuitable for a desired beneficial use. Surface or ground water pollution may be categorized into one or more of the following seven types depending on the nature of the substance causing the pollution: toxic pollution, organic pollution, nutrient pollution, pathogenic pollution, thermal pollution, sediment pollution, and aesthetic pollution. Water pollution is relative in the sense that whether or not a particular water resource is polluted is a function of the intended use of that water resource; that is, water may be polluted with respect to some uses and not polluted with respect to others.

There are many parameters or indicators available for measuring and describing water quality. Some of the more important indicators used in the analysis of stream water quality conditions in the Menomonee River watershed are: temperature, dissolved solids, undissolved solids, hydrogen ion concentration, chloride, dissolved oxygen, carbonaceous biochemical oxygen demand, nitrogenous biochemical oxygen demand, coliform bacteria, nutrients, aquatic flora and fauna, heavy metals and organic pesticides.

Water quality standards supporting the water use objectives for the surface water systems of the watershed provide a scale against which historic and existing water quality can be judged. The established water use objectives require that all of the surface waters satisfy minimum standards and that most of the stream system be suitable for recreational use and propagation of fish and aquatic life. Exceptions include Honey Creek, the South Branch of Underwood Creek, the lower portion of Underwood Creek, and the extreme lower reaches of the Menomonee River, all of which are in the less stringent restricted use category.

The following types of pollution sources have been identified in the Menomonee River watershed: municipal sewage treatment plants, sanitary and combined sewerage system flow relief points, industrial discharges, urban storm water runoff, and agricultural and other rural runoff. A variety of sources of field data extending back to 1951 was used to assess the quality of the watershed surface and ground water and to determine the probable cause of the polluted conditions that do exist in the basin.

Five municipal sewage treatment facilities existed in the watershed when the watershed planning program was initiated in 1972—the Village of Germantown Old Village and County Line Road plants, the Village of Menomonee Falls Pilgrim Road and Lilly Road plants, and the Village of Butler overflow-chlorination facility. The Germantown County Line Road facility was abandoned on November 2, 1973. All of the remaining four municipal sewage treatment plants in the Menomonee River watershed are scheduled to be abandoned, and therefore to cease discharging to the stream system of the watershed by 1981, upon completion of trunk sewer construction by the Milwaukee Metropolitan Sewerage Commissions and connection of the sanitary sewer service areas tributary to these four sewage treatment plants to the metropolitan system.

Sanitary sewage also enters the surface water system of the Menomonee River watershed surface waters through five types of sewerage system flow relief devices: combined sewer outfalls, crossovers, bypasses, relief pumping stations, and portable pumping stations. A total of 25 combined sewer outfalls plus 102 other flow relief devices are known to exist in the watershed with about 80 percent of 127 flow relief devices discharging directly to the Menomonee River. Forty percent of the flow relief devices, including all of the 25 combined sewer outfalls, are located within the Milwaukee County portion of the watershed. The 27-square-mile Milwaukee-Metropolitan area combined sewer service area, which includes a 10.7-square-mile area tributary to the Menomonee River, is the subject of a preliminary engineering study by a consulting firm retained by the Metropolitan Sewerage Commission, a study directed at the abatement of the combined sewer overflows. This study, which is scheduled for completion in 1977, is intended to build upon previous work by the Regional Planning Commission under the Milwaukee River watershed planning program and is to result in firm recommendations for construction of combined sewage conveyance and treatment facilities so as to abate pollution from the entire combined sewer service areas.

Industrial discharges, consisting primarily of cooling and process water, directly and indirectly enter the watershed stream system. A total of 44 industrial discharges—about half are cooling water—are known to exist within the watershed with over three-fourths discharging to the Menomonee River and about 85 percent being located in Milwaukee County. Although these discharges probably vary markedly in quality, very little data are currently available on the amount and quality of these discharges, a deficiency that will be rectified with the continued implementation of the Wisconsin Pollution Discharge Elimination System.

Diffuse, or nonpoint source, pollution consists of various discharges of pollutants to the surface waters that cannot be traced to specific discrete sources. Such pollution is carried from the urban and rural areas of the watershed, with the latter including animal feedlots, to the surface waters by means of surface runoff from the land and by interflow during and after runoff events as well as by baseflow—groundwater discharge—between such events. Three 24-hour synoptic water quality surveys conducted throughout the basin under the watershed planning program revealed relatively high phosphorus levels in land surface runoff from agricultural and separately sewered areas during a rainfall event. Some fecal coliform bacteria counts in water flowing from such areas were in excess of the level specified for recreational use. Total biochemical oxygen demand was found to be similar in rural areas and in separately sewered urban areas; the highest values—about 10 mg/1—were reported for the lowest flow periods. A positive aspect of runoff from the land surface, as revealed by the synoptic surveys, is a relatively high dissolved oxygen level which is then made available in the stream system for oxidation of organic materials.

It is estimated that erosion of sediment from the land surface of the Menomonee River watershed results in the transport of an average of about 98 tons per square mile per year, or 13,400 tons per year, of sediment from the basin by the Menomonee River. This relatively high value apparently reflects the urbanizing nature of the watershed. It is further estimated that if all of this sediment accumulates in the Menomonee River navigation channel—1.75 miles long and 75 to 100 feet wide—it would represent an annual volume of about 24,800 cubic yards and an accumulation of 10 inches per year. Sediment accumulation necessitates periodic maintenance dredging to maintain navigability depths required for commercial ships. Excessive sediment loads may also be expected to cause water quality problems and unstable channel conditions throughout the watershed.

An examination of Menomonee River watershed stream system water quality data for the period 1951 through 1974 indicates that the surface waters are severely polluted. Of the seven possible categories of pollution, six categories—toxic, organic, nutrient, pathogenic, sediment, and aesthetic—are known to exist in the Menomonee River watershed. The surface water pollution in the watershed is widespread in that it occurs on the Little Menomonee River, Underwood Creek, and Little Menomonee Creek, in addition to the Menomonee River. This clearly indicates that pollution problems may not be solely attributed to effluent from municipal sewage treatment plants or other point sources. The practical consequence of these polluted conditions is to severely restrict the use of the watershed stream system for aesthetic enjoyment, active recreational pursuits, propagation of fish and aquatic life, and industrial and commercial uses.

Low dissolved oxygen levels, very high fecal coliform bacteria counts, and excessive phosphorus have existed along the main stem of the Menomonee River over at least the past decade and probably for an even longer period. There is evidence also of excessive concentrations of lead, a toxic heavy metal. The Little Menomonee River exhibits high fecal coliform bacteria counts and excessive phosphorus levels. This major tributary, in addition, has occasionally contained substandard concentrations of dissolved oxygen and shows evidence of high lead concentrations. Further, portions of this stream contain creosote in the bottom muds in sufficient concentrations to cause severe chemical burns. Observed pollution problems on the Little Menomonee Creek, a rural area tributary to the Little Menomonee River, have been limited to excessive phosphorus levels. The two urban tributaries to the Menomonee River—Underwood Creek and Honey Creek—have both exhibited occasional instances of high fecal coliform bacteria counts and excessive phosphorus levels.

In addition to exhibiting overall substandard water quality conditions, surface water quality in the watershed is characterized by marked diurnal fluctuations and spatial variations. These temporal and spatial changes are more pronounced during periods of dry weather and low stream flows than during periods of wet weather and high stream flows. Dissolved oxygen levels, for example, were observed to range from very high supersaturated values during the day to low, substandard values during the night-time hours. Furthermore, while high, generally adequate dissolved oxygen concentrations occasionally occurred in the headwater areas of the Menomonee River, low substandard values were recorded in the middle and lower reaches of the River.

The most serious type of surface water pollution present in the watershed is pathogenic pollution as evidenced by the widespread occurrence of high fecal coliform bacteria counts. These fecal coliform counts, which indicate the presence of human and animal wastes, appear to be attributable to sanitary and combined sewer system overflows and runoff from the rural and urban land surfaces. The second most serious pollution problem is that of excessive nutrients, particularly phosphorus, under all flow conditions. It is estimated that only 40 percent of the phosphorus transported from the watershed by the Menomonee River may be attributable to sewage treatment plant discharge with the remaining 60 percent being attributable to land surface runoff and sanitary sewer overflow. The third most serious pollution problem is organic pollution reflected by occasional widespread substandard dissolved oxygen levels. This problem is more prevalent along the main stem of the Menomonee River. In addition to pathogenic, nutrient and organic pollution, toxic pollution in the form of high lead concentrations and the presence of creosote is a cause for concern, as is the sediment and aesthetic pollution that pervades the watershed surface water system.

Although the adopted water use objectives for the stream system call for recreational use and propagation of fish and aquatic life throughout most of the watershed, the surface waters currently receive only minimal use because of the severe pollution that exists. Improvement of surface water quality in the Menomonee River watershed so as to achieve the water use objectives will require a watershedwide water quality management effort aimed at both point and diffuse sources of pollution.

Ground Water Quality and Pollution

The amount and kind of dissolved minerals in groundwater differ greatly throughout the watershed and depend upon such factors as the amount and type of organic material in the soil; the solubility of rock over or through which the water moves; the length of time the groundwater is in contact with the soil and rock; and the temperature and pressure of the water. The natural environment of the watershed has been a far more important determinant of groundwater quality than have the effects of human activities in that groundwater, in contrast to surface water, is not so readily subject to contamination from urban and rural runoff and waste discharges.

A total of 192 groundwater quality samples from over 123 wells in and near the Menomonee River watershed were assembled and collated under the watershed study for the purpose of evaluating the quality of the groundwater resource. The sand and gravel aquifer may be expected to yield water containing iron and manganese in excess of the recommended standards for drinking water. In addition, water from this aquifer is considered "hard" for general domestic use and for some industrial-commercial uses. Water drawn from the dolomite aquifer may be expected to contain iron and manganese in excess of the concentrations set forth in drinking water standards. Although water from the dolomite aquifer is considered hard for general domestic use, none of the water utilities treats the water for hardness removal. Dolomite aquifer water is also considered hard for some industrial-commercial uses and, as a result, some self-supplied industrial-commercial users employ water softening processes. With respect to its use as drinking water, wells tapping the sandstone aquifer and wells tapping both the sandstone and dolomite aquifers may be expected to yield water containing iron, manganese, and sulfate in concentrations exceeding the recommended standards. In addition, water from the sandstone aquifer is considered hard for general domestic use and for some industrial-commercial uses, as is water from wells drawing on a combination of the dolomite and sandstone aquifers.

Mankind generates a great variety of pollutants from municipal, industrial, and agricultural wastes. Seepage of these wastes into shallow groundwater may occur from many potential sources in the Menomonee River watershed including, but not restricted to, private underground sewage disposal systems (septic tanks), refuse dumps, barnyards, cesspools and sewage lagoons, privies and dry wells, influent (losing) streams, industrial spillages, and leakage from community sewerage systems, all of which are more apt to affect the shallow aquifer than the deep aquifer.

Problems involving pollution of groundwater generally are much more difficult to correct than problems involving surface water, because the hidden paths of groundwater contaminants cannot be easily traced. An increased probability of groundwater pollution exists in residential areas using onsite waste disposal systems and private wells in areas where the water table is close to the land surface, where the soil is highly pervious permitting the relatively fast transport of pollutants, and in areas where the dolomite aquifer is creviced and extends to or near the land surface.

The glacial deposits overlying the dolomite in most of the watershed are sufficiently thick to prevent direct pollution of the dolomite aquifer. There is, however, a potential for pollution of the aquifer where it is covered by less than 50 feet of unconsolidated material. Such areas cover a total of 37.8 square miles—28 percent of the watershed—and are concentrated primarily in the northwestern corner of the watershed. Influent or losing stream reaches are a mechanism whereby pollutants may be transmitted into the sand and gravel aquifer and the dolomite aquifer. An analysis of the potentiometric surface of the shallow aquifers reveals that 22 miles of the watershed stream system may be influent. The influent reaches are well distributed around the watershed at locations on the Upper Menomonee River, the Lower Menomonee River, Underwood Creek, Honey Creek, Lilly Creek, Nor-X-Way Channel, and Dousman Ditch.

Although water from the watershed aquifers is chemically classified as hard and although water from some wells contains substandard concentrations of some constituents, the overall quality of groundwater in the Menomonee River watershed is markedly superior to stream water quality. There is very real potential for pollution problems to occur in the sand and gravel aquifer and in the dolomite aquifer. The groundwater resources of the watershed are relatively unspoiled and, if protected, can be relied upon as a continued source of water for domestic, commercial, and industrial use.

Water Use and Supply

About 80 percent of the watershed population receives Lake Michigan water through four public water utilities: the Milwaukee Water Works, the Wauwatosa Water Works, the West Allis Water Utility, and the Greendale Sewer and Water Utility. The spent water is discharged to the sanitary sewer system serving essentially the same geographic area, through which it is transported back out of the watershed for treatment before being returned to the Lake. The average daily supply of Lake Michigan water to the Menomonee River watershed is estimated at 48 million gallons. Inasmuch as the in-watershed portion of the Lake Michigan water supply system is not an integral part of the watershed hydrologic-hydraulic system, it is not considered further in the watershed study except as it might provide an alternative means of supplying water to those areas of Ozaukee, Washington, and Waukesha Counties that are not adequately served by public water supply systems.

Six percent of the watershed population is served by the following four public utilities which rely on groundwater drawn from the deep sandstone aquifer and the shallow dolomite aquifer: the Germantown Water Utility, the Menomonee Falls Water Utility, the Butler Water Utility, and the Brookfield Water Utility. These four utilities supply a total average flow of approximately 2.0 million gallons per day to the in-watershed portions of their service areas. Inventories conducted under the watershed planning program indicate that none of these groundwater utilities is experiencing serious water quantity or quality problems nor does any of them expect such problems to develop in the immediate future. Before initiating major additions to their water supply systems, the groundwater utilities are considering the findings of an engineering study that presents the results of an analysis of alternative intermunicipal water supply systems involving communities in and near the Menomonee River watershed. In light of the absence of serious existing or immediate future groundwater quality or quantity problems and the pending action resulting from the consultant's study, groundwater utilities are not considered further in the watershed planning process except as they might provide alternative means of providing water supply service to those contiguous urban areas not yet served by public water supply.

In spite of the present absence of problems, complacency toward the long-range reliance on groundwater under conditions of increased pumpage is not warranted. Analyses utilizing a simulation model of the sandstone aquifer indicate that the potentiometric surface of the deep aquifer can be expected to be drawn down an additional 250 to 400 feet in the Menomonee River watershed by the year 2000. This anticipated drawdown is in addition to a potentiometric surface decline of up to 400 feet in the Milwaukee area since the sandstone aquifer was first tapped by wells in 1880. The future drawdowns, the largest of which are expected to occur in the southwestern portion of the watershed, reflect increased regional groundwater use but are primarily attributed to large pumpage projections in the Waukesha-New Berlin area of Waukesha County.

The remaining 14 percent of the watershed population, located primarily in the City of Brookfield, the Village of Menomonee Falls, the Village of Elm Grove, the Village of Germantown, and the City of Mequon are served by private groundwater supplies which generally use relatively shallow wells that draw on the shallow sand and gravel aquifer. About 88 percent of the area served by such systems also uses onsite waste disposal systems and is located on soils not suited for such systems. As a result, instances have developed in recent years of aesthetic pollution including offensive odors and septic system discharge appearing in low areas and drainage swales. An even more serious concern is the health threat to area residents as a result of either direct contact with septic system discharge on the ground surface or as a result of the pollution of private groundwater supplies.

The ultimate resolution of these existing and potential water supply pollution problems associated with private groundwater supplies, as recommended in the adopted regional sanitary sewerage system plan, is the provision of sanitary sewer service to essentially all of those portions of the City of Brookfield and the Village of Menomonee Falls that lie within the Menomonee River watershed. Such service would eliminate the potential for pathogenic and aesthetic pollution from malfunctioning on-site sewage disposal systems in that portion of the watershed. The regional sanitary sewerage system plan also recommends that sanitary sewer service be provided to portions of the Village of Germantown and the City of Mequon which would similarly eliminate the potential pollution problems that now exist as a result of the use of both private water supplies and onsite sewage disposal systems in these communities.

Certain commercial and industrial water users in the Menomonee River watershed are self-supplied in that they satisfy all or part of their water needs from private wells or by pumping directly from the streams. Various types of cooling processes account for most of this water use. The self-supplied commercial-industrial water users rely primarily on wells, and 22 industrial-commercial groundwater users in the basin are known to have permits for high capacity wells. Investigations carried out under the watershed study reveal that self-supplied industrial-commercial water users are not experiencing any serious quantity or quality problems nor is their pumping interfering with that of the four groundwater utilities. Because of the absence of problems and because of the reserve provided by the eight municipal water utilities in the watershed, self-supplied industrial and commercial water use is not further addressed in the watershed plan.

CONCLUSION

This publication is the first of two volumes comprising the final planning report documenting the findings and recommendations of the Southeastern Wisconsin Regional Planning Commission on the comprehensive Menomonee River watershed planning program. Publication of Volume 1 marks completion of the first phase of the program. This phase has, of necessity, been directed to careful inventory, analyses, and forecast operations in order to provide the definitive knowledge of the existing and probable future state of the 137-square-mile watershed necessary as a basis for the preparation of a long-range development plan for the watershed.

The inventory findings and forecasts depict a dynamic and rapidly changing watershed, one in which the population may be expected to increase from about 348,000 to more than 388,000 persons by the year 2000, and one in which the area of land devoted to urban use may be expected to increase from about 73 square miles in 1970 to about 90 square miles by 2000. If existing trends are allowed to continue within the watershed, much of this new urban development will not be related intelligently to the underlying and sustaining natural resource base of the watershed, particularly to its soils, its streams and associated floodlands, its woodlands and wetlands, and its wildlife habitat areas, nor to the long established public utility systems and service areas. The deterioration and, in some cases, the complete destruction of the wetlands, woodlands, wildlife habitat areas, and potential park sites remaining within the watershed can be expected to continue, in the absence of a sound comprehensive watershed development plan and the implementation of that plan, as can surface water quality degradation and the encroachment of urban development onto the historic floodlands of the watershed.

The first phase of the watershed planning program and this, the first volume of the watershed planning report, have been confined to documenting the existing and probable future water resource and water resource-related problems of the watershed. This documentation necessarily provides the basis for the development of definitive plans and concrete recommendations for both the public works facility construction and the land and water management policies required to solve the pressing environmental and developmental problems existing within the watershed and thereby to realize the full potential of this important watershed. The alternative courses of action available for abating the problems of the Menomonee River watershed, together with recommendations for the best courses of action and the means for implementing them, are set forth in Volume 2 of this report.

APPENDICES

Appendix A

MENOMONEE RIVER WATERSHED COMMITTEE

Herbert A. Goetsch . . . . Commissioner of Public Works, City of Milwaukee
Chairman

J. William Little . . . . City Administrator, City of Wauwatosa
Vice-Chairman

Kurt W. Bauer . . . . Executive Director, SEWRPC
Secretary

Robert J. Borchardt . . . . Chief Engineer and General Manager, Milwaukee-Metropolitan Sewerage Commissions

Arthur D. Doll . . . . Director, Bureau of Planning, Wisconsin Department of Natural Resources

Glenn H. Evans . . . . Member, Citizens for Menomonee River Restoration, Inc.

Frederick E. Gottlieb . . . . Village Manager, Village of Menomonee Falls

Frank S. Hartay . . . . Plant Engineer, The Falk Corporation, Milwaukee

George C. Keller . . . . President, Wauwatosa State Bank

Raymond J. Kipp . . . . Dean, College of Engineering, Marquette University

Thomas M. Lee . . . . Chief, Flood Plain-Shoreland Management Section, Wisconsin Department of Natural Resources

Thomas P. Leisle . . . . Mayor, City of Mequon; Supervisor, Ozaukee County

Robert J. Mikula . . . . General Manager, Milwaukee County Park Commission

Thomas J. Muth . . . . Director of Public Works, Village of Germantown

Dennis Nulph . . . . District Engineer, Wisconsin Department of Natural Resources

Richard G. Reinders . . . . Trustee, Village of Elm Grove

John E. Schumacher . . . . City Engineer, City of West Allis

Walter J. Tarmann . . . . Executive Director, Waukesha County Park and Planning Commission

Clark E. Wangerin . . . . City Engineer, City of Brookfield

The following individuals also participated actively in the work of the Committee during preparation of the watershed plan: Robert E. Seaborn, former Plant Engineer, The Falk Corporation; William Manske, Sewer Research Engineer, Department of Public Works, City of Milwaukee; Donald G. Wieland, Director of Engineering, Milwaukee-Metropolitan Sewerage Commissions; Robert O. Hussa, Member, Citizens for Menomonee River Restoration; Irving Heipel, Landscape Architect, Milwaukee County Park Commission; Donald A. Roensch, Director of Public Works, City of Mequon; Ray D. Leary, former Chief Engineer and General Manager, Milwaukee-Metropolitan Sewerage Commissions; and Randall C. Melody, Chief Research Planner, Waukesha County Park and Planning Commission.

Appendix B

TECHNICAL ADVISORY COMMITTEE ON NATURAL RESOURCES AND ENVIRONMENTAL DESIGN

Appendix C

DATA FOR SYNOPTIC WATER QUALITY SURVEY NO. 1: APRIL 4, 1973

Sampling Station			Discharge		Water Quality Parameters[a]																												
Stream	Number	Time	cfs	mgd	Temperature (°F)	Dissolved Oxygen	pH (Standard Units)	Fecal Coliforms[b]	Chloride	Specific Conductivity[c]	Organic N	NH_3-N	NO_2-N	NO_3-N	Total N	Dissolved P	Total P	Turbidity (Formazin Units)	$CBOD_5$	$NBOD_5$	$TBOD_5$	Suspended Sediments (Tons/Day)	Cadium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	Undissolved Solids	Undissolved Volatile Solids	Total Volatile Solids	Total Solids
Menomonee River	Mn-1	0740	--	--	39.0	8.0	7.6	15	40	713	1.27	0.15	0.011	3.19	4.62	--	0.05	2.5	1.2[d]	0.3[d]	1.5[d]	--	--	--	--	--	--	--	--	--	--	--	--
		1310	--	--	41.0	10.4	7.8	--	52	722	1.27	<0.03	0.042	2.77	4.08	0.086	0.09	2.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1930	--	--	42.0	11.8	7.8	25	27	710	1.13	0.31	0.025	2.68	4.15	0.027	0.19	4.0	--	--	2.1	--	--	--	--	--	--	--	--	--	--	--	--
		0125	--	--	39.0	9.3	7.6	--	47	706	1.16	0.04	0.019	2.22	3.44	0.094	0.09	2.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-2	0750	--	--	40.0	8.7	7.7	20	45	737	1.22	0.24	0.033	3.52	5.01	0.353	0.40	4.5	--	--	1.5	--	--	--	--	--	--	--	--	--	--	--	--
		1320	--	--	42.0	10.4	7.7	--	51	756	1.02	0.10	0.062	3.21	4.39	0.243	0.34	3.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1950	--	--	43.0	11.2	7.8	20	45	736	1.02	0.15	0.063	2.24	3.47	0.263	0.45	6.2	--	--	2.4	--	--	--	--	--	--	--	--	--	--	--	--
		0135	--	--	41.0	10.0	7.8	--	52	749	0.91	0.07	0.037	1.90	2.92	0.289	0.32	4.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-3	0806	--	--	40.0	9.5	7.7	30	49	771	0.90	0.31	0.043	3.08	4.33	0.248	0.30	7.6	--	--	1.8	--	--	--	--	--	--	--	--	--	--	--	--
		0955	44.3	28.62	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.7	--	--	--	--	--	--	--	--	--	--	--
		1330	--	--	42.0	10.2	7.7	--	52	793	1.08	0.06	0.045	2.77	3.96	0.318	0.37	7.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		2006	--	--	42.0	11.4	7.8	25	48	769	1.03	0.05	0.023	2.16	3.26	0.269	0.46	9.7	--	--	1.8	--		--	--	--	--	--	--	--	--	--	--
		0145	--	--	40.0	10.5	7.9	--	52	757	1.08	0.17	0.056	1.54	2.86	--	0.23	9.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-4	0830	--	--	40.0	11.7	7.9	10,000	52	736	1.15	0.48	0.037	2.65	4.32	0.448	0.51	11.0	--	--	2.8	--	--	--	--	--	--	--	--	--	--	--	--
		1345	--	--	42.0	12.6	8.1	--	62	796	1.11	0.09	0.063	2.63	3.89	--	0.27	7.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		2020	--	--	42.0	10.8	8.0	<1,000	57	794	1.14	0.21	0.045	2.13	3.53	0.527	0.49	10.0	--	--	4.9	--	--	--	--	--	--	--	--	--	--	--	--
		0200	--	--	41.0	11.1	8.0	--	76	814	1.02	0.43	0.071	1.78	3.30	--	0.39	11.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-5	0630	--	--	41.0	9.9	7.9	15	80	858	0.86	0.87	0.049	2.85	4.63	0.372	0.46	9.0	2.9[d]	2.4[d]	5.3[d]	--	--	--	--	--	--	--	--	--	--	--	--
		1230	--		42.0	11.0	8.0	--	100	921	1.10	0.38	0.061	2.03	3.57	0.415	0.43	14.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1830	--	--	43.0	12.4	8.1	130	82	868	1.02	0.52	0.055	1.97	3.57	0.434	0.67	10.0	--	--	4.3	--	--	--	--	--	--	--	--	--	--	--	--
		0040	--	--	41.0	10.5	8.0	--	81	862	0.99	0.57	0.075	1.86	3.50	0.518	0.55	11.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-6	0620	--	--	41.0	9.7	7.9	60	79	872	1.13	0.93	0.054	3.01	5.12	0.587	0.72	8.0	--		2.8	--	--	--	--	--	--	--	--	--	--	--	--
		1220	--	--	41.0	11.2	7.9	--	95	893	1.14	0.59	0.051	3.05	4.83	0.345	0.40	7.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1820	--	--	42.0	11.4	8.1	150	81	918	1.08	0.52	0.052	2.40	4.05	0.386	0.54	10.0	--	--	3.7	--	--	--	--	--	--	--	--	--	--	--	--
		0025	--	--	41.0	10.3	8.0	--	96	875	0.80	0.52	0.089	1.54	2.95	0.663	0.58	8.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-7a	0600	--	--	41.0	9.5	8.0	120	100	979	0.20	0.60	0.046	2.61	3.46	0.404	0.70	12.5	--	--	3.0	--	--	--	--	--	--	--	--	--	--	--	--
		1200	--	--	42.0	10.6	8.0	--	119	880	1.02	0.42	0.099	2.92	4.46	0.406	0.39	30.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1800	--	--	43.0	13.0	8.1	250	95	921	1.06	0.33	0.050	2.38	3.82	0.294	0.48	14.0	--	--	3.4	--	--	--	--	--	--	--	--	--	--	--	--
		0010	--	--	41.0	11.0	8.0	--	119	913	0.90	0.43	0.066	1.86	3.26	--	0.31	13.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-7b	0820	--	--	41.0	10.6	8.0	<10	98	942	1.02	0.89	0.043	2.38	4.33	0.513	0.72	13.0	--	--	2.1	--	--	--	--	--	--	--	--	--	--	--	--
		1420	--	--	42.0	11.5	7.9	--	105	890	1.02	0.28	0.081	2.95	4.33	--	0.28	22.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		2020	--	--	42.0	11.8	8.1	360	90	930	0.84	0.21	0.055	0.97	2.07	--	0.73	16.0	--	--	2.4	--	--	--	--	--	--	--	--	--	--	--	--
		0220	--	--	41.0	10.9	8.0	--	105	921	1.07	0.40	0.080	2.16	3.71	--	0.29	14.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-10	0745	--	--	42.0	11.0	7.9	120	105	1,031	0.62	0.62	0.037	1.81	3.09	0.404	0.34	13.0	3.1[d]	0.7[d]	3.8[d]	--	--	--	--	--	--	--	--	--	--	--	--
		1345	--	--	43.0	11.1	7.9	--	81	750	0.96	0.45	0.104	2.10	3.61	0.324	0.38	56.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1405	248	160.21	--	--	--	--	--	--	--	--	--	--	2.02	0.265	0.27	28.5	--	--	4.6	--	--	--	--	--	--	--	--	--	--	--	--
		1945	--	--	43.0	11.1	8.1	2,300	94	942	0.70	0.15	0.044	1.13	2.50	0.271	0.43	20.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		0145	--	--	42.0	11.1	8.0	--	110	1,005	0.73	0.21	0.077	1.48	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-14	0700	--	--	42.0	10.7	8.0	<10	100	992	0.72	1.19	0.048	2.01	3.97	--	0.26	14.0	--	--	1.5	--	--	--	--	--	--	--	--	--	--	--	--
		1300	--	--	42.0	11.0	8.1	--	95	846	1.49	0.35	0.080	1.77	3.69	0.375	0.49	44.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1900	--	--	43.0	10.9	8.0	3,400	92	886	1.02	0.23	0.063	2.10	3.41	0.268	0.39	24.0	--	--	3.7	--	--	--	--	--	--	--	--	--	--	--	--
		0100	--	--	42.0	10.9	8.0	--	124	982	1.01	0.26	0.081	1.24	2.59	--	0.33	17.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-15	0640	--	--	57.0	3.0	7.6	210	105	942	0.74	1.59	0.061	2.63	5.02	--	0.23	9.0	--	--	3.4	--	--	--	--	--	--	--	--	--	--	--	--
		1240	--	--	57.0	4.2	7.7	--	115	915	1.02	0.77	0.070	1.86	3.72	0.263	0.39	11.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1840	--	--	55.0	4.2	7.7	440	84	910	0.92	0.80	0.060	2.08	3.86	0.187	0.25	7.8	--	--	2.8	--	--	--	--	--	--	--	--	--	--	--	--
		0040	--	--	57.0	6.7	7.8	--	95	923	0.93	0.48	0.104	1.40	2.91	0.297	0.29	6.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-18	0755	--	--	42.0	11.2	7.8	500	57	350	1.72	0.55	0.120	1.29	3.68	0.454	0.61	130.0	3.0	6.0	9.0	--	--	--	--	--	--	--	--	--	--	--	--
		1355	--		42.0	10.9	7.7	--	129	802	1.13	0.23	0.172	2.84	4.39	--	0.27	73.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1925	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.0	3.0	9.0	--	--	--	--	--	--	--	--	--	--	--	--
		1955	--	--	43.0	10.6	7.8	200	104	686	1.16	<0.03	0.134	1.98	3.27	0.442	0.40	85.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		0155	--	--	44.0	10.9	7.9	--	304	2,373	0.25	0.06	0.072	5.11	5.49	--	0.17	9.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-19	0725	--	--	45.0	9.9	7.8	3,100	144	1,185	0.67	0.45	0.040	1.53	2.69	0.186	0.22	37.0	6.0	6.0	12.0	--	--	--	--	--	--	--	--	--	--	--	--
		1325	--	--	46.0	9.5	7.7	--	41	563	2.38	1.41	0.077	1.43	5.30	0.416	1.49	30.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1925	--	--	45.0	9.7	7.8	8,500	150	1,158	0.98	0.21	0.066	0.99	2.25	0.236	0.46	31.0	4.0	9.0	13.0	--	--	--	--	--	--	--	--	--	--	--	--
		0125	--	--	45.0	9.6	7.8	--	167	1,416	0.46	0.07	0.058	1.17	1.76	0.209	0.18	8.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Village of	0505	--	--	49.1	7.7	7.9	--	148	1,215	1.33	1.02	1.571	2.99	6.91	8.403	9.18	3.4	<10.0	>0.0	<10.0	--	--	--	--	--	--	--	--	--	--	--	--
	Germantown	1000	--	--	50.0	7.8	7.9	--	197	1,336	1.22	2.00	0.284	4.13	7.63	8.166	8.67	3.6	<10.0	>0.0	<10.0	--	--	--	--	--	--	--	--	--	--	--	--
	Old Village Sewage	1655	--	--	50.0	7.0	7.7	--	158	1,224	1.89	1.88	2.784	0.33	6.89	7.606	9.24	6.6	13.0	4.0	17.0	--	--	--	--	--	--	--	--	--	--	--	--
	Treatment Plant	2250	--	--	50.0	7.2	7.8	--	148	1,190	1.31	1.72	0.106	0.06	3.20	11.913	10.23	4.0	<10.0	>0.0	<10.0	--	--	--	--	--	--	--	--	--	--	--	--
	Village of	0530	--	--	44.6	7.8	8.1	--	313	1,736	1.66	7.37	0.153	0.22	9.40	4.420	4.99	6.8	11.0	10.0	21.0	--	--	--	--	--	--	--	--	--	--	--	--
	Germantown	1120	--	--	45.5	8.9	8.0	--	467	2,082	1.68	6.35	0.680	0.32	9.03	2.207	3.02	11.5	16.0	4.0	20.0	--	--	--	--	--	--	--	--	--	--	--	--
	County Line Sewage	1715	--	--	45.5	8.7	8.1	--	342	1,879	1.30	6.09	0.320	0.19	7.90	2.207	2.97	12.0	11.0	12.0	23.0	--	--	--	--	--	--	--	--	--	--	--	--
	Treatment Plant	2310	--	--	46.4	7.7	8.2	--	291	1,638	1.50	7.20	0.121	0.09	8.91	3.417	5.36	7.0	16.0	14.0	30.0	--	--	--	--	--	--	--	--	--	--	--	--

Sampling Station			Discharge		Water Quality Parameters[a]																												
Stream	Number	Time	cfs	mgd	Temperature (°F)	Dissolved Oxygen	pH (Standard Units)	Fecal Coliforms[b]	Chloride	Specific Conductivity[c]	Organic N	NH_3-N	NO_2-N	NO_3-N	Total N	Dissolved P	Total P	Turbidity (Formazin Units)	$CBOD_5$	$NBOD_5$	$TBOD_5$	Suspended Sediments (Tons/Day)	Cadium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	Undissolved Solids	Undissolved Volatile Solids	Total Volatile Solids	Total Solids
Menomonee River	Village of Menomonee Falls Pilgrim Road Sewage Treatment Plant	0540	--	--	53.6	8.7	7.8	--	385	1,934	2.29	3.39	0.268	5.45	11.40	3.181	4.70	13.6	<10.0	>0.0	<10.0	--	--	--	--	--	--	--	--	--	--	--	--
		1130	--	--	53.6	8.0	7.8	--	279	1,652	2.63	7.98	0.512	5.05	16.17	3.919	6.93	15.0	<10.0	>0.0	<10.0	--	--	--	--	--	--	--	--	--	--	--	--
		1730	--	--	53.6	7.8	7.8	--	216	1,414	2.17	4.48	0.550	4.66	11.86	6.190	7.13	15.0	<10.0	>5.0	15.0	--	--	--	--	--	--	--	--	--	--	--	--
	Village of Menomonee Falls Lilly Road Sewage Treatment Plant	2320	--	--	53.6	6.0	7.7	--	284	1,637	2.58	4.71	0.651	3.64	11.58	5.305	6.87	15.0	11.0	3.0	14.0	--	--	--	--	--	--	--	--	--	--	--	--
		0550	--	--	44.6	9.7	8.1	240	313	1,786	1.57	6.42	0.824	0.51	9.32	6.190	7.33	4.0	3.7	4.9	8.6	--	--	--	--	--	--	--	--	--	--	--	--
		1145	--	--	44.6	10.2	8.1	30	313	1,926	1.46	7.82	0.599	1.03	10.91	6.869	8.04	4.9	--	--	6.7	--	--	--	--	--	--	--	--	--	--	--	--
		1750	--	--	44.6	10.3	8.1	60	313	1,773	1.60	6.63	0.588	0.50	9.32	6.220	7.01	4.8	3.1	3.6	6.7	--	--	--	--	--	--	--	--	--	--	--	--
		2335	--	--	44.6	10.0	8.1	<100	313	1,798	1.47	7.48	0.526	0.45	9.93	6.544	8.18	4.5	3.7	4.9	8.6	--	--	--	--	--	--	--	--	--	--	--	--
	Village of Butler Overflow Chlorination Facility	0615	--	--	49.1	9.2	7.9	--	153	1,290	3.50	3.75	0.102	1.41	8.76	1.382	3.11	16.0	<10.0	>0.0	<10.0	--	--	--	--	--	--	--	--	--	--	--	--
		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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	S. K. Williams Company Discharge	0630	--	--	50.0	66.2	7.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.046	0.18	0.10	0.04	<0.0002	0.52	2.10	--	--	--	--
		1200	--	--	53.6	66.2	8.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.550	0.24	0.34	0.03	<0.0002	1.00	2.20	--	--	--	--
		1810	--	--	51.8	77.0	7.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.520	0.23	0.18	0.04	0.0002	0.83	2.30	--	--	--	--
		2355	--	--	60.8	71.6	7.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.070	0.15	0.14	0.03	<0.0002	0.49	2.10	--	--	--	--
	Milwaukee Road Railroad Yard Oil Separator	0705	--	--	66.2	5.6	6.2	--	--	--	--	--	--	--	--	--	--	--	<30.0	>1.0	31.0	--	--	--	--	--	--	--	--	60	35	145	920
		1215	--	--	66.2	7.1	9.2	--	--	--	--	--	--	--	--	--	--	--	<30.0	>31.0	61.0	--	--	--	--	--	--	--	--	135	45	120	470
		1830	--	--	77.0	5.3	9.1	--	--	--	--	--	--	--	--	--	--	--	40.0	26.0	66.0	--	--	--	--	--	--	--	--	95	65	150	640
		0020	--	--	71.6	--	8.6	--	--	--	--	--	--	--	--	--	--	--	<30.0	>13.0	43.0	--	--	--	--	--	--	--	--	70	45	120	730
Little Menomonee River	Mn-7	0610	--	--	40.0	9.4	7.8	40	102	1,001	0.89	0.32	0.022	2.17	3.40	--	0.06	7.0	--	--	1.2	--	--	--	--	--	--	--	--	--	--	--	--
		1210	--	--	41.0	10.8	7.9	--	95	902	1.03	<0.03	0.056	2.79	3.88	--	0.08	25.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1810	--	--	42.0	13.3	8.0	65	88	887	0.85	<0.03	0.031	2.00	2.88	0.054	0.15	17.5	--	--	2.8	--	--	--	--	--	--	--	--	--	--	--	--
		0015	--	--	40.0	10.8	8.0	--	105	959	0.76	0.03	0.039	1.74	2.57	--	0.05	11.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-11	0700	--	--	40.0	9.2	7.7	65	47	806	0.97	0.17	0.019	3.45	4.61	--	0.06	5.0	1.0[d]	0.9[d]	1.9[d]	--	--	--	--	--	--	--	--	--	--	--	--
		1255	--	--	42.0	12.4	7.9	--	40	813	1.18	0.17	0.019	3.65	5.02	--	0.05	5.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1900	--	--	42.0	11.6	7.8	50	38	806	1.22	0.20	0.016	3.45	4.89	0.101	0.12	4.6	--	--	2.8	--	--	--	--	--	--	--	--	--	--	--	--
		0105	--	--	39.0	10.1	7.8	--	57	800	1.09	0.16	0.049	3.07	4.37	0.065	0.07	5.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-17	0640	--	--	39.0	9.2	7.8	70	168	1,014	0.66	0.43	0.045	1.95	3.09	--	0.08	20.0	1.2	1.5	2.7	--	--	--	--	--	--	--	--	--	--	--	--
		1240	--	--	42.0	11.8	8.0	--	105	702	1.15	0.18	0.052	2.18	3.56	--	0.14	44.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1845	--	--	42.0	12.0	7.6	65	124	846	0.58	0.05	0.039	1.10	1.77	0.115	0.15	25.0	1.8	1.5	3.3	--	--	--	--	--	--	--	--	--	--	--	--
		0055	--	--	37.0	10.1	7.9	--	148	983	0.71	0.06	0.062	1.03	1.86	--	0.09	23.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	4-0870.5	0800	10.2	6.59	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.67	--	--	--	--	--	--	--	--	--	--	--
Little Menomonee Creek	Mn-16	0715	--	--	39.0	11.3	7.9	90	52	892	0.40	0.52	0.024	2.34	3.28	--	0.07	3.0	0.9	1.5	2.4	--	--	--	--	--	--	--	--	--	--	--	--
		1300	--	--	42.0	13.2	8.1	--	62	861	0.68	0.38	0.036	3.86	4.96	--	0.07	3.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1915	--	--	42.0	11.5	7.4	700	49	864	0.99	0.40	0.023	2.78	4.10	0.309	0.34	2.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		0115	--	--	38.0	11.4	7.9	--	47	875	0.68	0.14	0.083	3.04	3.94	--	0.09	4.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Underwood Creek	Mn-8	0830	--	--	40.0	12.1	8.0	950	162	1,117	1.12	0.32	0.063	2.05	3.65	--	0.28	62.0	--	--	5.8	--	--	--	--	--	--	--	--	--	--	--	--
		1300	29.3	18.93	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.70	--	--	--	--	--	--	--	--	--	--	--
		1430	--	--	43.0	12.1	8.0	--	158	1,161	1.04	0.29	0.084	1.81	3.22	0.115	0.14	20.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		2030	--	--	41.0	11.7	8.1	50	161	1,168	1.01	<0.03	0.048	0.79	1.85	0.099	0.12	14.5	--	--	2.5	--	--	--	--	--	--	--	--	--	--	--	--
		0230	--	--	38.0	12.2	8.0	--	158	1,164	0.76	0.30	0.060	1.63	2.75	--	0.09	11.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-12	0600	--	--	40.0	10.2	8.0	50	110	1,119	0.97	0.36	0.011	1.78	3.12	--	0.05	4.5	--	--	1.5	--	--	--	--	--	--	--	--	--	--	--	--
		1200	--	--	40.0	13.0	8.0	--	124	1,039	0.91	0.08	0.062	1.98	3.03	0.141	0.12	16.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1800	--	--	42.0	12.6	8.1	50	114	1,035	0.86	0.26	0.014	1.63	2.76	0.075	0.07	6.5	--	--	2.1	--	--	--	--	--	--	--	--	--	--	--	--
		0001	--	--	40.0	11.0	7.9	--	129	1,029	1.19	0.20	0.055	0.77	2.22	--	0.04	4.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Honey Creek	Mn-9	0805	--	--	45.0	11.0	8.0	520	105	1,120	0.43	0.31	0.037	1.53	2.31	0.024	0.10	23.5	3.4[d]	1.0[d]	4.4[d]	--	--	--	--	--	--	--	--	--	--	--	--
		1115	10.1	6.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	34.00	--	--	--	--	--	--	--	--	--	--	--
		1405	--	--	45.0	11.2	7.9	--	86	698	1.31	0.53	0.128	1.84	3.81	0.297	0.74	64.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		2005	--	--	45.0	10.8	8.0	410	88	954	0.62	0.03	0.046	0.58	1.28	0.167	0.16	41.5	--	--	5.2	--	--	--	--	--	--	--	--	--	--	--	--
		0205	--	--	44.0	11.1	7.9	--	85	1,038	0.48	0.07	0.054	1.23	1.83	--	0.06	24.0	--	--	--	3.30	--	--	--	--	--	--	--	--	--	--	--
		0910	18.5	11.95	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-13	0615	--	--	40.0	10.8	7.9	120	168	1,093	0.52	0.42	0.050	1.60	2.59	--	0.14	23.5	--	--	0.9	--	--	--	--	--	--	--	--	--	--	--	--
		1215	--	--	41.0	12.2	7.9	--	124	694	0.99	0.16	0.109	1.21	2.47	--	0.23	84.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1815	--	--	41.0	11.4	8.0	110	103	822	0.81	0.03	0.062	1.73	2.63	--	0.17	50.5	--	--	3.7	--	--	--	--	--	--	--	--	--	--	--	--
		0015	--	--	37.0	11.3	8.0	--	144	972	0.58	0.12	0.049	1.16	1.91	0.101	0.12	24.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

[a] *Values are in mg/l except as indicated.*

[b] *Values are in MFFCC/100 ml.*

[c] *Values are in micro-mhos/cm at 77°F.*

[d] *Composite sample made up from the first and third sample periods.*

Source: Wisconsin Department of Natural Resources, U. S. Geological Survey, and SEWRPC.

Appendix D

DATA FOR SYNOPTIC WATER QUALITY SURVEY NO. 2: JULY 18, 1973

Water Quality Parameters[a] (part 1)

Stream	Sampling Station Number	Time	Discharge cfs	Discharge mgd	Temperature (°F)	Dissolved Oxygen	pH (Standard Units)	Fecal Coliforms[b]	Chloride	Specific Conductivity[c]	Organic N	NH_3-N	NO_2-N	NO_3-N	Total N	Dissolved P	Total P
Menomonee River	Mn-1	0825	--	--	67.0	7.5	7.9	100	35	715	0.80	0.11	0.039	5.45	6.40	0.013	0.07
		1310	--	--	74.0	8.9	8.0	--	35	699	0.95	0.13	0.039	5.62	6.74	0.016	0.05
		1955	--	--	76.5	8.6	8.1	200	32	694	0.73	0.11	0.043	6.30	7.18	0.013	0.05
		0115	--	--	71.0	10.4	8.0	--	31	703	0.89	0.15	0.040	5.06	6.14	0.012	0.07
	Mn-2	0845	--	--	73.0	13.2	8.5	<100	67	810	1.83	0.22	0.171	3.94	6.16	0.926	1.06
		1320	--	--	72.0	16.4	8.4		68	828	2.16	0.12	0.178	3.71	6.17	0.913	1.07
		2010	--	--	76.5	19.3	8.6	<100	67	794	1.69	0.09	0.178	3.34	5.30	0.846	1.15
		0125	--	--	76.5	19.1	8.8	--	68	799	1.69	0.19	0.160	1.89	3.93	0.823	1.15
	Mn-3	0900	--	--	71.0	5.3	8.2	600	57	781	0.96	<0.03	0.076	3.34	4.38	0.541	0.65
		1140	4.21	2.72	--	--	--	--	--	--	--	--	--	--	--	--	--
		1330	--	--	76.0	11.2	8.5	--	57	757	1.17	0.06	0.073	3.18	4.48	0.535	0.69
		2020	--	--	80.0	16.0	8.8	100	59	751	1.22	0.06	0.071	2.82	4.17	0.496	0.66
		0130	--	--	75.0	7.9	8.7	--	62	750	1.19	0.04	0.060	1.69	2.98	0.500	0.65
	Mn-4	0915	--	--	70.0	4.2	7.8	3,000	95	951	1.39	0.57	0.393	4.03	6.38	1.592	1.81
		1340	--	--	79.0	8.8	8.1	--	226	1,352	1.34	0.76	0.376	5.09	7.57	1.398	1.81
		2030	--	--	79.5	6.4	8.2	<1,000	123	175	1.17	1.58	0.806	4.85	8.41	1.581	1.63
		0145	--	--	72.0	2.3	7.9	--	115	1,034	1.20	1.67	0.588	2.91	6.37	1.893	2.15
	Mn-5	0700	--	--	70.0	1.5	7.8	100	212	1,273	1.20	0.59	0.514	2.17	4.47	2.296	2.35
		1230	--	--	77.0	7.7	8.0	--	205	1,227	1.58	0.64	0.776	1.65	4.66	2.207	2.25
		1855	--	--	79.5	12.8	8.6	300	168	1,103	1.23	0.11	0.490	2.13	3.96	1.693	1.81
		0035	--	--	75.0	2.6	8.0	--	147	1,081	1.14	0.15	0.247	2.19	3.73	1.981	2.08
	Mn-6	0645	--	--	69.0	4.1	7.9	200	190	1,233	1.08	0.10	0.057	2.17	3.41	1.798	1.70
		1220	--	--	75.0	9.7	8.3	--	161	1,150	1.06	0.11	0.031	2.85	4.05	--	0.14
		1845	--	--	78.0	11.1	8.6	300	147	1,096	0.98	0.07	0.018	2.48	3.55	1.669	1.44
		0025	--	--	73.0	6.0	8.2	--	214	1,261	1.01	0.06	0.036	2.19	3.30	1.899	1.71
	Mn-7a	0805	--	--	68.0	4.2	8.0	400	132	1,079	1.39	0.16	0.046	1.37	2.96	1.002	1.06
		1200	--	--	75.0	6.4	8.0	--	149	1,060	1.66	0.38	0.043	2.08	4.16	--	0.82
		1825	--	--	79.0	10.2	8.5	200	166	1,097	1.09	0.05	0.024	2.04	3.20	0.896	0.84
		0005	--	--	78.0	9.8	8.5	--	180	1,166	1.06	0.22	0.058	1.60	2.94	--	0.80
	Mn-7b	0830	--	--	70.0	4.5	8.0	100	121	1,053	0.86	<0.03	0.017	0.83	1.71	0.908	0.84
		1415	--	--	75.0	10.3	8.1	--	127	1,054	0.99	<0.03	0.018	0.76	1.77	0.830	0.80
		2030	--	--	76.0	11.1	8.6	100	143	1,064	1.01	<0.03	0.014	1.05	2.07	0.719	0.79
		0215	--	--	73.0	7.7	8.4	--	138	1,070	0.92	<0.03	0.012	1.31	2.24	0.784	0.77
	Mn-10	0745	--	--	66.0	8.2	8.0	100	123	1,136	0.69	0.09	0.009	0.32	1.11	0.212	0.25
		1336	--	--	72.0	13.2	8.4	--	98	1,047	0.63	0.08	0.009	1.50	2.22	0.200	0.28
		1505	27.4	17.70	--	--	--	--	--	--	--	--	--	--	--	--	--
		1946	--	--	70.0	8.7	8.2	<100	91	1,054	0.70	0.06	0.017	1.03	1.81	0.200	0.28
		0125	--	--	66.0	6.0	8.1	--	106	1,221	0.58	0.05	0.009	1.16	1.80	0.244	0.24
	Mn-14	0715	--	--	68.0	3.1	7.4	3,600	90	1,030	0.96	0.30	0.050	0.27	1.58	0.277	0.31
		1315	--	--	73.0	10.7	7.9	--	90	1,044	0.87	0.05	0.011	0.15	1.08	0.321	0.38
		1920	--	--	76.0	10.2	8.4	3,700	91	980	0.89	0.11	0.035	0.14	1.17	0.392	0.41
		0055	--	--	72.0	2.6	7.9	--	94	938	0.77	0.30	0.044	0.13	1.24	0.330	0.39
	Mn-15	0646	--	--	74.0	4.5	7.8	100	74	769	0.95	0.43	0.042	0.44	1.86	0.148	0.21
		1245	--	--	77.0	6.4	7.8	--	74	761	1.17	0.36	0.044	0.24	1.81	0.152	0.26
		1910	--	--	76.0	4.1	7.7	200	69	739	1.17	0.37	0.043	0.40	1.98	0.150	0.23
		0030	--	--	74.0	4.7	7.7	--	69	706	0.99	0.58	0.040	0.25	1.86	0.137	0.20
	Mn-18	0800	--	--	62.0	9.0	7.9	<100	193	1,370	0.35	<0.03	0.021	5.10	5.47	0.048	0.08
		1345	--	--	63.0	9.2	8.0	--	197	1,345	0.31	0.10	0.022	12.22	12.65	0.060	0.08
		2000	--	--	63.0	8.9	8.0	300	241	1,600	0.28	<0.03	0.022	5.24	5.54	0.048	0.04
		0135	--	--	63.0	8.8	8.0	--	278	1,491	0.26	0.09	0.027	11.89	12.27	--	0.04
	Mn-19	0730	--	--	61.0	5.5	7.3	830,000	158	1,324	1.70	4.98	0.096	0.89	7.67	1.179	1.49
		1330	--	--	65.0	2.3	6.9	--	91	1,054	13.39	10.02	0.138	0.78	24.33	7.778	13.63
		1930	--	--	63.0	3.2	7.1	6,400,000	95	936	7.00	8.01	0.075	0.24	15.33	3.943	5.82
		0115	--	--	62.0	4.2	7.2	--	95	1,054	3.24	6.63	0.032	0.09	9.99	2.387	3.09
	Village of Germantown Old Village Sewage Treatment Plant	0515	--	--	64.4	7.0	7.8	--	129	1,243	1.69	0.74	1.361	0.59	4.38	8.963	8.10
		1050	--	--	68.0	7.3	7.9	--	260	1,681	2.88	1.02	0.205	2.55	6.66	7.901	6.90
		1600	--	--	69.8	7.1	7.8	--	231	1,524	1.23	0.61	0.135	4.31	6.29	8.904	9.58
		2255	--	--	68.0	7.0	7.8	--	202	1,465	2.71	0.16	0.033	4.33	7.23	7.606	8.21
	Village of Germantown County Line Sewage Treatment Plant	0535	--	--	60.8	3.2	8.0	--	390	2,042	3.81	12.41	0.973	0.63	17.82	4.290	4.17
		1115	--	--	62.6	3.9	7.9	--	429	2,173	3.30	10.87	1.243	1.36	16.77	4.614	9.01
		1615	--	--	64.4	4.7	7.9	--	501	2,332	3.51	11.04	1.264	1.17	16.98	4.437	4.96
		2310	--	--	62.6	3.8	7.9	--	438	2,260	4.14	8.09	1.541	1.50	15.27	5.441	4.74
	Village of Menomonee Falls Pilgrim Road Sewage Treatment Plant	0545	--	--	68.0	6.7	7.7	--	187	1,437	3.15	1.33	0.776	6.30	11.56	5.145	5.42
		1125	--	--	70.7	6.8	7.7	--	424	2,124	4.10	8.97	1.073	6.69	20.83	4.422	3.99
		1630	--	--	73.4	6.2	7.6	--	202	1,504	4.24	7.49	0.800	5.73	18.26	4.260	4.96
		2320	--	--	70.7	6.1	7.6	--	173	1,411	7.03	7.29	0.866	4.46	19.65	5.396	6.22
	Village of Menomonee Falls Lilly Road Sewage Treatment Plant	0735	--	--	69.8	9.2	8.6	<100	255	1,805	5.82	3.82	0.075	0.15	9.87	3.478	3.48
		1135	--	--	76.1	5.1	8.5	<100	274	1,761	5.36	7.67	0.307	0.26	13.60	4.437	4.85
		1650	--	--	77.0	5.7	8.5	<100	298	1,772	6.96	4.66	0.072	0.14	11.83	4.260	4.79
		2335	--	--	75.2	5.1	8.4	100	298	1,800	6.33	6.08	0.168	0.26	12.84	4.910	6.62
	Village of Butler Overflow Chlorination Facility	0610	--		62.6	7.6	9.6	--	419	2,210	6.68	3.43	0.060	0.47	10.64	0.280	0.52
		1200	--	--	68.0	4.9	7.4	--	158	1,362	8.39	20.93	0.071	1.63	31.02	0.725	2.08
		1715	--	--	68.0	4.3	8.8	--	40	1,187	8.50	16.55	0.101	0.68	25.83	3.588	7.21
		2355	--	--	66.2	--	8.4		76	1,313	13.81	29.04	0.122	1.19	44.16	1.915	5.05
	S. K. Williams Company	0620	--	--	62.6	7.8	8.6	--	--	--	--	--	--	--	--	--	--
		1210	--	--	68.0	7.8	8.8	--	--	--	--	--	--	--	--	--	--
		1730	--	--	69.8	7.3	8.9	--	--	--	--	--	--	--	--	--	--
		0010	--	--	68.0	7.4	8.9	--	--	--	--	--	--	--	--	--	--
	Milwaukee Road Railroad Yard	0650	--	--	62.6	5.4	7.7	--	--	--	--	--	--	--	--	--	--
		1245	--	--	73.4	5.4	8.0	--	--	--	--	--	--	--	--	--	--
		1800	--	--	71.6	5.5	7.9	-	--	--	--	--	--	--	--	--	--
		0030	--	--	71.6	4.4	7.9	--	--	--	--	--	--	--	--	--	--

Water Quality Parameters[a] (part 2)

Sampling Station Number	Time	Turbidity (Formazin Units)	$CBOD_5$	$NBOD_5$	$TBOD_5$	Suspended Sediments (Tons/Day)	Cadium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	Undissolved Solids	Undissolved Volatile Solids	Total Volatile Solids	Total Solids
Mn-1	0825	8.1	1.2[d]	0.9[d]	2.1[d]	--	--	--	--	--	--	--	--	--	--	--	--
	1310	7.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1955	8.7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0115	10.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mn-2	0845	11.0	--	--	7.0	--	--	--	--	--	--	--	--	--	--	--	--
	1320	16.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	2010	13.0	--	--	7.8	--	--	--	--	--	--	--	--	--	--	--	--
	0125	24.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mn-3	0900	18.0	--	--	3.7	--	--	--	--	--	--	--	--	--	--	--	--
	1140	--	--	--	--	0.40	--	--	--	--	--	--	--	--	--	--	--
	1330	14.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	2020	10.0	--	--	6.1	--	--	--	--	--	--	--	--	--	--	--	--
	0130	17.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mn-4	0915	15.0	--	--	7.8	--	--	--	--	--	--	--	--	--	--	--	--
	1340	8.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	2030	8.0	--	--	6.5	--	--	--	--	--	--	--	--	--	--	--	--
	0145	12.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mn-5	0700	3.0	1.8[d]	2.1[d]	3.9[d]	--	--	--	--	--	--	--	--	--	--	--	--
	1230	5.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1855	12.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0035	8.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mn-6	0645	6.7	--	--	2.9	--	--	--	--	--	--	--	--	--	--	--	--
	1220	5.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1845	4.9	--	--	7.0	--	--	--	--	--	--	--	--	--	--	--	--
	0025	7.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mn-7a	0805	22.0	--	--	3.3	--	--	--	--	--	--	--	--	--	--	--	--
	1200	14.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1825	9.0	--	--	2.5	--	--	--	--	--	--	--	--	--	--	--	--
	0005	15.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mn-7b	0830	4.5	--	--	2.9	--	--	--	--	--	--	--	--	--	--	--	--
	1415	3.7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	2030	5.5	--	--	2.5	--	--	--	--	--	--	--	--	--	--	--	--
	0215	4.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mn-10	0745	5.0	1.1	1.2	2.3	--	--	--	--	--	--	--	--	--	--	--	--
	1336	4.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1505	--	--	--	--	2.60	--	--	--	--	--	--	--	--	--	--	--
	1946	5.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0125	4.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mn-14	0715	3.2	--	--	5.3	--	--	--	--	--	--	--	--	--	--	--	--
	1315	5.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1920	4.0	--	--	4.5	--	--	--	--	--	--	--	--	--	--	--	--
	0055	2.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mn-15	0646	4.6	--	--	4.5	--	--	--	--	--	--	--	--	--	--	--	--
	1245	5.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1910	6.0	--	--	4.9	--	--	--	--	--	--	--	--	--	--	--	--
	0030	5.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mn-18	0800	1.50	1.2	1.2	2.4	--	--	--	--	--	--	--	--	--	--	--	--
	1345	1.60	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	2000	1.40	0.8	0.8	1.6	--	--	--	--	--	--	--	--	--	--	--	--
	0135	1.30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mn-19	0730	12.00	20.0	24.0	44.0	--	--	--	--	--	--	--	--	--	--	--	--
	1330	32.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1930	44.00	114.0	157.0	271.0	--	--	--	--	--	--	--	--	--	--	--	--
	0115	21.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Village of Germantown Old Village Sewage Treatment Plant	0515	1.40	3.7	1.6	5.3	--	--	--	--	--	--	--	--	--	--	--	--
	1050	2.00	--	--	2.5	--	--	--	--	--	--	--	--	--	--	--	--
	1600	1.70	--	--	1.5	--	--	--	--	--	--	--	--	--	--	--	--
	2255	1.50	2.1	1.3	3.4	--	--	--	--	--	--	--	--	--	--	--	--
Village of Germantown County Line Sewage Treatment Plant	0535	4.30	11.0	>9.0	>20.0	--	--	--	--	--	--	--	--	--	--	--	--
	1115	3.50	12.0	13.0	25.0	--	--	--	--	--	--	--	--	--	--	--	--
	1615	4.20	11.0	10.0	21.0	--	--	--	--	--	--	--	--	--	--	--	--
	2310	5.30	13.0	>15.0	>28.0	--	--	--	--	--	--	--	--	--	--	--	--
Village of Menomonee Falls Pilgrim Road Sewage Treatment Plant	0545	5.10	1.0	6.0	10.0	--	--	--	--	--	--	--	--	--	--	--	--
	1125	13.00	6.4	4.6	11.0	--	--	--	--	--	--	--	--	--	--	--	--
	1630	15.00	5.5	1.6	7.1	--	--	--	--	--	--	--	--	--	--	--	--
	2320	25.00	12.0	10.0	22.0	--	--	--	--	--	--	--	--	--	--	--	--
Village of Menomonee Falls Lilly Road Sewage Treatment Plant	0735	10.00	14.0	17.0	31.0	--	--	--	--	--	--	--	--	--	--	--	--
	1135	7.70	>30.0	>0.0	>30.0	--	--	--	--	--	--	--	--	--	--	--	--
	1650	11.00	16.0	14.0	30.0	--	--	--	--	--	--	--	--	--	--	--	--
	2335	9.00	16.0	13.0	29.0	--	--	--	--	--	--	--	--	--	--	--	--
Village of Butler Overflow Chlorination Facility	0610	36.00	>32.0	>0.0	>32.0	--	--	--	--	--	--	--	--	--	--	--	--
	1200	53.00	>32.0	>0.0	>32.0	--	--	--	--	--	--	--	--	--	--	--	--
	1715	61.00	>30.0	>0.0	>30.0	--	--	--	--	--	--	--	--	--	--	--	--
	2355	55.00	>30.0	>0.0	>30.0	--	--	--	--	--	--	--	--	--	--	--	--
S. K. Williams Company	0620	--	--	--	--	--	0.05	0.20	0.05	0.10	<0.0002	0.50	2.30	--	--	--	--
	1210	--	--	--	--	--	0.25	0.30	0.15	0.05	<0.0002	0.40	2.10	--	--	--	--
	1730	--	--	--	--	--	0.21	0.15	0.65	0.02	<0.0002	1.00	2.50	--	--	--	--
	0010	--	--	--	--	--	0.09	0.20	0.20	0.04	0.0002	0.30	2.10	--	--	--	--
Milwaukee Road Railroad Yard	0650	--	<10.0	>1.0	11.0	--	--	--	--	--	--	--	--	15	10	60	390
	1245	--	<10.0	>6.0	16.0	--	--	--	--	--	--	--	--	25	15	75	375
	1800	--	<10.0	>5.0	15.0	--	--	--	--	--	--	--	--	15	10	70	355
	0030	--	14.0	7.0	21.0	--	--	--	--	--	--	--	--	20	10	75	410

Sampling Station: Stream	Sampling Station: Number	Time	Discharge: cfs	Discharge: mgd	Water Quality Parameters[a]: Temperature (°F)	Dissolved Oxygen	pH (Standard Units)	Fecal Coliforms[b]	Chloride	Specific Conductivity[c]	Organic N	NH_3-N	NO_2-N	NO_3-N	Total N	Dissolved P	Total P	Turbidity (Formazin Units)	$CBOD_5$	$NBOD_5$	$TBOD_5$	Suspended Sediments (Tons/Day)	Cadium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	Undissolved Solids	Undissolved Volatile Solids	Total Volatile Solids	Total Solids
Little Menomonee River	Mn-7	0625	--	--	66.0	2.7	7.7	200	74	842	0.96	0.14	0.019	0.34	1.46	0.170	0.18	9.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1210	--	--	77.0	10.5	8.1	--	69	800	0.90	0.09	0.006	0.32	1.32	0.092	0.10	9.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1835	--	--	82.0	13.4	8.2	400	74	842	0.81	0.06	0.005	0.16	1.03	0.084	0.12	8.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		0025	--	--	74.0	6.4	8.1	--	69	818	0.88	0.08	0.007	0.18	1.15	0.130	0.10	9.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-11	0750	--	--	69.0	4.7	7.7	400	27	804	1.05	0.07	0.028	2.77	3.92	0.030	3.92	5.3	1.1	1.6	2.7	--	--	--	--	--	--	--	--	--	--	--	--
		1245	--	--	70.0	10.2	7.8	--	28	866	0.95	0.08	0.028	2.41	3.47	0.013	3.47	4.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1925	--	--	71.5	12.7	8.1	200	27	775	0.89	<0.03	0.023	2.74	3.65	0.030	3.65	7.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		0055	--	--	68.5	6.2	7.9	--	26	782	0.90	0.04	0.023	2.69	3.65	0.019	3.65	7.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-17	0730	--	--	68.0	6.5	7.8	100	99	837	0.80	<0.03	0.007	0.04	0.81	0.007	0.02	3.8	0.8	1.6	2.40	--	--	--	--	--	--	--	--	--	--	--	--
		1235	--	--	85.0	9.5	8.2	--	106	826	0.79	<0.03	0.008	0.00	0.80	0.010	0.04	5.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1910	--	--	79.5	8.1	8.4	300	105	800	0.87	<0.03	0.007	0.07	0.95	0.021	0.05	5.8	8.0	20.0	28.00	--	--	--	--	--	--	--	--	--	--	--	--
		0040	--	--	75.0	4.6	7.8	--	106	862	0.79	<0.03	0.006	<0.04	0.80	0.015	0.04	7.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	4-0870.5	1245	0.60	0.39	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.10	--	--	--	--	--	--	--	--	--	--	--
Little Menomonee Creek	Mn-16	0810	--	--	63.0	7.4	7.9	1,000	21	970	0.94	0.03	0.011	2.03	3.01	0.079	0.13	14.0	0.4	2.0	2.4	--	--	--	--	--	--	--	--	--	--	--	--
		1250	--	--	71.0	9.8	8.1	--	16	973	0.95	0.03	0.010	1.81	2.80	0.054	0.10	8.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1935	--	--	71.5	7.0	8.1	800	20	940	0.81	<0.03	0.007	1.71	2.53	0.063	0.10	6.5	0.8	2.0	2.8	--	--	--	--	--	--	--	--	--	--	--	--
		0105	--	--	67.5	7.3	8.0	--	21	1,012	0.86	0.05	0.011	1.71	2.63	0.084	0.11	9.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Underwood Creek	Mn-8	0845	--	--	69.0	9.3	8.2	600	124	1,203	0.66	0.03	0.005	0.00	0.70	0.011	0.03	2.6	2.2	1.1	3.3	--	--	--	--	--	--	--	--	--	--	--	--
		1020	3.16	2.04	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.02	--	--	--	--	--	--	--	--	--	--	--
		1430	--	--	89.0	8.6	8.1	--	129	1,133	0.69	<0.03	0.004	0.00	0.69	0.010	0.03	2.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		2030	--	--	76.0	7.0	8.0	500	134	1,184	0.70	<0.03	0.004	<0.04	0.70	0.009	0.04	2.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		0215	--	--	69.0	6.7	8.0	--	143	1,250	0.65	<0.03	0.007	<0.04	0.66	0.006	0.04	2.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-12	0600	--	--	60.0	5.8	7.4	100	137	1,396	0.64	<0.03	0.014	0.15	0.80	0.009	0.02	4.5	--	--	2.5	--	--	--	--	--	--	--	--	--	--	--	--
		1200	--	--	65.0	10.5	7.6	--	139	1,400	0.73	<0.03	<0.002	0.13	0.86	<0.005	0.02	3.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1830	--	--	66.0	8.5	7.6	100	144	1,418	0.74	0.03	0.002	0.13	0.90	0.014	0.03	3.9	--	--	2.9	--	--	--	--	--	--	--	--	--	--	--	--
		0001	--	--	63.5	5.5	7.4	--	130	1,345	0.77	0.04	0.005	0.07	0.88	0.052	0.06	3.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Honey Creek	Mn-9	0815	--	--	57.0	9.8	7.9	200	36	982	0.35	<0.03	0.005	<0.04	0.36	0.011	0.02	7.2	1.2	0.4	1.6	--	--	--	--	--	--	--	--	--	--	--	--
		0845	9.38	6.06	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.30	--	--	--	--	--	--	--	--	--	--	--
		1400	--	--	67.0	11.9	7.9	--	32	899	0.36	<0.03	0.009	0.00	0.37	0.016	0.02	11.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		2005	--	--	63.0	8.7	8.0	100	31	930	0.36	<0.03	0.026	0.06	0.45	0.010	0.02	12.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		0150	--	--	58.0	8.7	8.0	--	34	982	0.31	<0.03	0.009	0.05	0.39	0.010	0.03	9.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-13	0615	--	--	66.0	3.3	7.6	300	129	826	0.67	<0.03	0.005	0.17	0.84	0.033	0.05	3.2	--	--	2.5	--	--	--	--	--	--	--	--	--	--	--	--
		1215	--	--	81.0	15.5	8.5	--	132	846	0.69	0.04	0.003	0.13	0.86	0.019	0.05	3.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1815	--	--	82.0	11.1	9.1	100	115	663	0.82	0.06	0.004	0.13	1.01	0.015	0.06	3.0	--	--	4.9	--	--	--	--	--	--	--	--	--	--	--	--
		0015	--	--	72.0	3.3	7.8	--	110	760	0.81	0.05	0.008	0.16	1.03	0.071	0.10	3.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

[a] *Values are in mg/l except as indicated.*

[b] *Values are in MFFCC/100 ml.*

[c] *Values are in micro-mhos/cm at 77°F.*

[d] *Composite sample made up from the first and third sample periods.*

Source: Wisconsin Department of Natural Resources, U. S. Geological Survey, and SEWRPC.

Appendix E

DATA FOR SYNOPTIC WATER QUALITY SURVEY NO. 3: AUGUST 6, 1974

Sampling Station: Stream	Sampling Station: Number	Time	Discharge: cfs	Discharge: mgd	Temperature (°F)	Dissolved Oxygen	pH (Standard Units)	Fecal Coliforms[b]	Chloride	Specific Conductivity[c]	Organic N	NH_3-N	NO_2-N	NO_3-N	Total N	Dissolved P	Total P	Turbidity (Formazin Units)	$CBOD_5$	$NBOD_5$	$TBOD_5$	Suspended Sediments (Tons/Day)	Cadium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	Undissolved Solids	Undissolved Volatile Solids	Total Volatile Solids	Total Solids
					Water Quality Parameters[a]																												
Menomonee River	Mn-1	0960	-	-	66.0	8.7	8.1	480	35	664	0.99	0.23	0.026	2.43	3.676	0.025	0.05	3.3	1.0[d]	0.6[d]	1.6[d]	-	-	-	-	-	-	-	-	-	-	-	-
		1530	-	-	68.0	8.3	8.1	-	35	720	1.02	0.16	0.036	2.80	4.019	0.024	0.05	2.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		2145	-	-	66.5	9.7	8.1	290	37	724	1.03	0.12	0.029	2.66	3.835	0.055	0.05	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		0325	-	-	64.0	10.1	8.1	-	31	734	0.92	0.07	0.019	2.83	3.839	0.017	0.05	13.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mn-2	1010	-	-	70.5	7.3	8.1	160	77	832	2.33	1.83	0.128	0.75	5.042	1.026	1.04	2.8	-	-	7.4	-	-	-	-	-	-	-	-	-	-	-	-
		1545	-	-	74.0	8.5	8.2	-	69	854	2.29	1.63	0.722	0.79	4.826	1.067	0.96	2.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		2200	-	-	74.0	11.3	8.3	180	72	832	2.27	1.40	0.128	0.62	4.422	0.884	0.82	2.9	-	-	14.0	-	-	-	-	-	-	-	-	-	-	-	-
		0335	-	-	72.0	8.6	8.3	-	60	853	1.82	1.16	0.099	0.70	3.789	0.884	1.07	8.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mn-3	1015	-	-	66.5	5.4	8.0	980	67	715	1.55	1.16	0.165	0.14	3.010	0.687	0.74	27.0	-	-	10.0	-	-	-	-	-	-	-	-	-	-	-	-
		1550	-	-	73.0	8.5	8.2	-	67	781	1.54	1.01	0.177	0.77	3.510	0.669	0.80	5.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		1655	3.83	2.47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.54	-	-	-	-	-	-	-	-	-	-	-
		2210	-	-	72.0	8.0	8.0	270	67	728	1.66	0.77	0.209	0.79	3.322	0.625	0.73	22.0	-	-	9.8	-	-	-	-	-	-	-	-	-	-	-	-
		0345	-	-	68.0	4.1	8.1	-	52	808	1.59	0.62	0.214	0.89	3.310	0.660	0.77	38.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mn-4	1025	-	-	68.0	5.3	7.8	1,100	106	982	1.50	0.76	0.435	3.11	5.800	--	2.28	6.9	-	-	14.0	-	-	-	-	-	-	-	-	-	-	-	-
		1605	-	-	78.0	9.0	8.1	-	253	1,398	1.51	1.33	0.518	3.98	7.338	0.825	0.98	8.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		2225	-	-	71.6	4.7	7.9	2,100	126	1,067	1.65	0.89	0.474	3.62	6.641	--	1.43	6.4	-	-	11.0	-	-	-	-	-	-	-	-	-	-	-	-
		0400	-	-	67.0	4.2	7.8	-	91	1,010	1.31	0.89	0.329	2.98	5.508	0.996	1.41	29.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mn-5	0900	-	-	68.0	3.3	7.8	3,300	134	1,206	1.94	2.26	0.538	2.67	7.406	1.473	1.28	7.3	2.5[d]	2.5[d]	5.0[d]	-	-	-	-	-	-	-	-	-	-	-	-
		1445	-	-	76.0	6.6	8.0	-	163	1,174	2.50	1.76	0.523	2.62	7.361	0.971	1.21	16.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		2040	-	-	73.5	6.9	8.0	930	148	1,131	2.33	1.28	0.592	2.55	6.760	--	1.21	35.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		0230	-	-	70.0	3.8	7.9	-	163	1,292	1.62	0.79	0.383	3.51	6.292	1.059	1.31	32.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mn-6	0845	-	-	67.0	5.8	8.1	530	148	898	2.00	0.24	0.152	2.88	5.283	0.990	0.60	25.0	-	-	9.2	-	-	-	-	-	-	-	-	-	-	-	-
		1435	-	-	73.5	11.6	8.2	-	221	1,174	1.78	0.29	0.167	3.84	6.077	--	0.67	9.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		2030	-	-	72.0	8.7	7.8	610	187	1,227	1.99	0.52	0.232	3.48	6.219	--	0.77	5.8	-	-	9.2	-	-	-	-	-	-	-	-	-	-	-	-
		0220	-	-	69.0	4.0	7.9	-	139	1,226	1.63	0.25	0.215	3.42	5.521	0.872	0.98	29.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mn-7a	0820	-	-	67.0	5.6	8.3	2,100	158	950	1.84	0.31	0.067	1.79	4.009	--	0.49	5.4	-	-	6.1	-	-	-	-	-	-	-	-	-	-	-	-
		1410	-	-	72.0	9.9	8.4	-	177	1,163	1.79	0.17	0.072	2.09	4.115	0.666	0.78	14.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		2015	-	-	74.0	11.7	8.7	310	177	1,067	1.71	0.19	0.079	2.28	4.263	0.595	0.59	5.9	-	-	10.0	-	-	-	-	-	-	-	-	-	-	-	-
		0205	-	-	70.0	6.8	8.5	-	119	1,043	1.62	0.07	0.053	2.23	3.966	0.554	0.74	24.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mn-7b	0805	-	-	66.5	6.2	8.2	680	158	1,120	1.52	0.27	0.034	1.69	3.510	0.398	0.45	13.0	-	-	5.5	-	-	-	-	-	-	-	-	-	-	-	-
		1355	-	-	73.5	11.5	8.5	-	148	1,021	1.61	0.18	0.031	1.41	3.127	0.398	0.42	8.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		2000	-	-	73.5	11.6	8.9	410	139	1,025	1.56	0.24	0.032	1.29	3.116	0.377	0.47	8.0	-	-	9.8	-	-	-	-	-	-	-	-	-	-	-	-
		0145	-	-	70.0	6.7	8.6	-	124	1,016	1.49	0.05	0.017	1.58	3.133	0.510	0.59	14.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mn-10	0720	-	-	68.0	6.1	8.1	800	139	1,034	1.26	0.16	0.018	0.78	2.219	0.501	0.55	2.5	1.6[d]	0.7[d]	2.3[d]	-	-	-	-	-	-	-	-	-	-	-	-
		1136	16.90	10.92	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.32	-	-	-	-	-	-	-	-	-	-	-
		1325	-	-	73.0	15.5	8.6	-	156	951	1.22	0.21	0.021	0.94	2.392	0.331	0.39	2.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		1925	-	-	73.5	8.6	8.5	660	161	962	1.20	0.22	0.012	0.72	2.153	0.405	0.41	2.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		0110	-	-	70.0	5.5	8.2	-	152	1,086	1.04	0.07	0.054	0.96	2.124	0.288	0.31	4.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mn-14	0656	-	-	67.0	3.9	7.8	6,200	127	958	1.16	0.20	0.019	0.58	1.957	0.209	0.27	3.6	-	-	4.9	-	-	-	-	-	-	-	-	-	-	-	-
		1300	-	-	71.0	10.2	8.1	-	118	923	1.32	0.19	0.017	0.30	1.833	0.421	0.42	3.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		1855	-	-	74.0	12.8	8.9	620	130	923	1.29	0.18	0.015	0.40	1.862	0.353	0.40	3.6	-	-	6.8	-	-	-	-	-	-	-	-	-	-	-	-
		0050	-	-	70.0	3.9	7.7	-	115	833	0.85	0.09	0.017	0.44	1.388	0.182	0.31	9.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mn-15	0635	-	-	69.5	0.4	7.4	26,000	62	516	1.32	0.67	0.002	0.09	2.082	0.118	0.22	3.0	-	-	7.4	-	-	-	-	-	-	-	-	-	-	-	-
		1245	-	-	73.5	2.4	7.6	-	48	471	1.22	0.64	0.005	0.15	2.021	0.081	0.18	3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		1845	-	-	71.5	4.4	7.7	3,600	43	695	1.15	0.46	0.004	0.13	1.753	0.067	0.14	2.5	-	-	8.0	-	-	-	-	-	-	-	-	-	-	-	-
		0035	-	-	71.6	5.2	7.6	-	57	563	1.09	0.40	0.013	0.14	1.640	0.102	0.24	8.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mn-18	0730	-	-	64.0	9.2	8.0	290	216	1,624	0.42	< 0.03	0.009	5.14	5.588	0.011	0.02	2.5	4.3	3.1	7.4	-	-	-	-	-	-	-	-	-	-	-	-
		1335	-	-	67.0	9.3	8.0	-	235	1,708	0.30	< 0.03	0.009	5.45	5.765	0.012	0.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		1930	-	-	63.5	9.8	8.1	800	231	1,695	0.26	0.05	0.015	5.19	5.517	0.014	0.02	1.1	4.9	3.7	8.6	-	-	-	-	-	-	-	-	-	-	-	-
		0115	-	-	64.5	8.6	7.4	-	197	1,216	0.47	< 0.03	0.010	3.74	4.232	0.011	0.02	11.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mn-19	0710	-	-	57.0	9.3	7.9	590	168	1,695	1.43	< 0.03	0.003	1.13	2.572	0.079	0.09	1.8	4.3	6.1	10.4	-	-	-	-	-	-	-	-	-	-	-	-
		1315	-	-	57.0	9.4	7.9	-	177	1,735	1.39	< 0.03	0.003	1.08	2.494	--	0.03	2.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		1910	-	-	57.0	8.8	7.8	5,400	173	1,749	1.43	< 0.03	0.002	1.02	2.473	< 0.005	0.07	4.4	8.0	5.5	13.5	-	-	-	-	-	-	-	-	-	-	-	-
		0100	-	-	58.0	8.6	7.1	-	176	1,419	1.24	0.05	0.003	0.60	1.891	0.052	0.15	27.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Village of Germantown Old Village Sewage Treatment Plant	0510	-	-	69.8	8.4	8.5	-	90	896	1.87	1.78	0.206	3.14	6.997	2.446	2.75	5.4	6.0	5.0	11.0	-	-	-	-	-	-	-	-	-	-	-	-
		1110	-	-	73.4	17.2	8.6	20	76	886	2.80	1.56	0.219	2.65	7.225	1.443	1.64	3.4	4.0	6.0	10.0	-	-	-	-	-	-	-	-	-	-	-	-
		1710	-	-	77.0	18.4	8.9	20	71	890	2.14	1.56	0.205	2.85	6.757	1.561	1.44	2.3	7.0	8.0	15.0	-	-	-	-	-	-	-	-	-	-	-	-
		2345	-	-	73.4	18.8	9.0	< 10	71	887	1.85	1.39	0.214	2.57	6.022	1.413	1.27	5.5	7.5	4.9	12.0	-	-	-	-	-	-	-	-	-	-	-	-
	Village of Menomonee Falls Pilgrim Road Sewage Treatment Plant	0530	-	-	69.8	21.0	7.4	-	192	1,447	3.08	3.94	0.290	8.85	16.157	3.538	3.99	6.6	10.4	8.6	19.0	-	-	-	-	-	-	-	-	-	-	-	-
		1130	-	-	69.8	3.0	7.6	-	443	2,209	3.46	7.06	0.498	8.85	19.875	1.517	2.92	25.0	11.0	10.0	21.0	-	-	-	-	-	-	-	-	-	-	-	-
		1725	-	-	71.6	7.0	7.6	-	221	1,494	3.44	5.00	0.444	8.54	17.425	1.458	2.15	16.0	9.0	13.0	22.0	-	-	-	-	-	-	-	-	-	-	-	-
		2305	-	-	69.8	5.8	7.4	-	163	1,366	3.54	4.98	0.359	7.38	16.239	2.107	3.32	9.2	2.0	17.0	19.0	-	-	-	-	-	-	-	-	-	-	-	-
	Village of Menomonee Falls Lilly Road Sewage Treatment Plant	0540	-	-	71.6	19.4	8.8	< 10	366	1,978	4.86	7.76	0.341	0.98	13.945	1.399	2.18	6.8	1.0	11.0	12.0	-	-	-	-	-	-	-	-	-	-	-	-
		1145	-	-	71.6	22.2	9.2	< 10	380	1,953	4.92	7.44	0.343	1.48	14.187	1.546	2.55	6.7	4.0	11.0	15.0	-	-	-	-	-	-	-	-	-	-	-	-
		1740	-	-	73.4	24.3	9.1	40	385	1,926	5.37	6.83	0.372	1.40	13.609	1.207	2.10	6.7	6.0	11.0	17.0	-	-	-	-	-	-	-	-	-	-	-	-
		2320	-	-	71.0	19.0	9.0	< 10	371	1,974	5.37	7.87	0.341	1.38	14.962	1.620	2.21	6.2	4.0	14.0	18.0	-	-	-	-	-	-	-	-	-	-	-	-
	Village of Butler Overflow Chlorination Facility	0610	-	-	62.6	4.5	7.4	-	728	2,936	19.70	8.01	0.165	0.82	28.696	2.239	6.17	27.0	> 100.0	> 50.0	> 150.0	-	-	-	-	-	-	-	-	-	-	-	-
		1205	-	-	66.2	4.2	7.4	-	231	1,700	10.26	17.89	0.152	0.22	28.519	3.965	6.94	42.0	> 100.0	> 50.0	> 150.0	-	-	-	-	-	-	-	-	-	-	-	-
		1755	-	-	66.2	10.0	6.8	-	119	1,415	19.70	20.61	0.171	0.82	41.300	13.484	19.70	27.0	> 100.0	> 50.0	> 150.0	-	-	-	-	-	-	-	-	-	-	-	-
		2340	-	-	64.4	2.8	6.8	-	95	1,315	13.82	18.55	0.207	0.77	33.346	9.806	15.02	38.0	> 100.0	> 50.0	> 150.0	-	-	-	-	-	-	-	-	-	-	-	-
	S. K. Williams Company	0620	-	-	62.6	9.1	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	0.20	0.05	0.10	< 0.0002	0.50	2.30	-	-	-	-
		1215	-	-	68.0	9.0	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.25	0.30	0.15	0.05	< 0.0002	0.40	2.10	-	-	-	-
		1805	-	-	68.0	8.2	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.21	0.15	0.65	0.02	< 0.0002	1.00	2.50	-	-	-	-
		2355	-	-	66.2	8.0	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09	0.20	0.20	0.04	< 0.0002	0.30	2.10	-	-	-	-
	Milwaukee Road Railroad	0650	-	-	73.4	5.8	9.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	255	130	290	1,590
		1240	-	-	77.0	7.3	9.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	135	65	220	830
		1830	-	-	73.4	7.3	6.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35	20	180	1,070
		0020	-	-	73.4	6.9	9.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	40	210	850

Sampling Station			Discharge		Water Quality Parameters[a]																												
Stream	Number	Time	cfs	mgd	Temperature (°F)	Dissolved Oxygen	pH (Standard Units)	Fecal Coliforms[b]	Chloride	Specific Conductivity[c]	Organic N	NH_3-N	NO_2-N	NO_3-N	Total N	Dissolved P	Total P	Turbidity (Formazin Units)	$CBOD_5$	$NBOD_5$	$TBOD_5$	Suspended Sediments (Tons/Day)	Cadium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	Undissolved Solids	Undissolved Volatile Solids	Total Volatile Solids	Total Solids
Little Menomonee River	Mn-7	0830	--	--	64.5	8.0	8.1	360	60	555	1.18	0.33	0.035	0.25	1.795	0.125	0.14	32.0	--	--	7.4	--	--	--	--	--	--	--	--	--	--	--	--
		1425	--	--	73.0	9.6	8.3	--	52	533	1.11	0.21	0.024	0.27	1.621	0.054	0.11	17.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		2020	--	--	75.0	8.3	8.4	370	62	614	1.08	0.20	0.016	0.25	1.544	0.068	0.15	4.3	--	--	8.0	--	--	--	--	--	--	--	--	--	--	--	--
		0210	--	--	67.0	4.2	7.9	--	45	775	0.85	<0.03	0.015	0.26	1.139	0.068	0.15	30.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-11	0930	--	--	61.5	7.0	8.0	1,300	139	762	1.07	0.21	0.027	3.58	4.881	0.059	0.11	3.6	1.0[d]	0.2[d]	1.2[d]	--	--	--	--	--	--	--	--	--	--	--	--
		1510	--	--	68.0	10.0	8.1	--	137	739	1.14	0.21	0.020	2.91	4.286	0.054	0.09	4.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		2115	--	--	66.0	7.2	7.9	860	139	771	1.11	0.15	0.018	3.04	4.310	0.034	0.09	4.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		0255	--	--	63.0	6.5	7.9	--	24	843	1.05	0.07	0.031	2.27	3.416	0.071	0.11	22.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-17	0915	--	--	67.5	9.7	7.8	650	62	524	1.13	0.16	0.029	0.14	1.459	--	0.05	37.0	5.5	3.7	9.2	--	--	--	--	--	--	--	--	--	--	--	--
		1500	--	--	83.5	14.1	8.1	--	81	629	1.07	<0.03	0.014	0.11	1.213	0.040	0.07	26.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		2300	--	--	74.0	4.3	7.8	850	101	796	0.77	<0.03	0.011	0.15	0.945	0.051	0.06	33.0	8.0	4.9	12.9	--	--	--	--	--	--	--	--	--	--	--	--
		0240	--	--	66.0	4.7	7.8	--	106	850	0.79	<0.03	0.008	0.13	0.945	0.041	0.06	28.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	4-0870.5	1720	0.82	0.53	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.09	--	--	--	--	--	--	--	--	--	--	--
Little Menomonee Creek	Mn-16	0945	--	--	62.0	8.6	8.1	810	19	1,214	1.30	0.09	0.003	1.67	3.059	0.039	0.09	8.5	5.5	3.1	8.6	--	--	--	--	--	--	--	--	--	--	--	--
		1520	--	--	68.0	9.5	8.1	--	25	1,221	1.15	0.09	0.004	1.74	2.978	0.033	0.09	7.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		2130	--	--	65.0	6.4	7.9	2,400	22	1,257	1.44	0.17	0.004	2.07	3.684	0.028	0.10	6.5	7.4	4.3	11.7	--	--	--	--	--	--	--	--	--	--	--	--
		0310	--	--	62.5	6.8	8.0	--	18	960	0.98	0.06	0.009	1.20	2.240	0.053	0.10	25.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Underwood Creek	Mn-8	0810	--	--	64.5	9.3	8.3	1,700	168	1,216	0.76	0.22	0.008	0.09	1.075	0.022	0.04	3.5	2.0[d]	0.8[d]	2.8[d]	--	--	--	--	--	--	--	--	--	--	--	--
		1400	--	--	83.0	12.2	8.6	--	173	1,067	0.81	0.22	0.009	0.10	1.152	0.031	0.04	4.4	--	--	--	0.03	--	--	--	--	--	--	--	--	--	--	--
		1530	2.16	1.59	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		2005	--	--	75.0	7.0	8.3	3,100	168	1,024	0.80	0.25	0.011	0.10	1.169	0.026	0.05	5.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		0155	--	--	67.0	7.3	8.1	--	119	1,124	0.66	0.05	<0.002	0.12	0.833	0.031	0.04	4.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-12	0600	--	--	60.0	6.1	7.7	80	202	1,346	0.70	0.08	<0.002	0.17	0.943	0.005	0.03	2.0	--	--	4.3	--	--	--	--	--	--	--	--	--	--	--	--
		1200	--	--	65.0	13.1	7.9	--	192	1,346	0.67	0.12	<0.002	0.11	0.893	0.108	0.13	2.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1800	--	--	66.0	10.2	7.8	30	187	1,288	0.72	0.14	<0.002	<0.04	0.894	0.010	0.04	2.6	--	--	6.1	--	--	--	--	--	--	--	--	--	--	--	--
		0001	--	--	62.5	5.3	7.5	--	148	1,768	0.51	<0.03	<0.002	<0.04	0.568	0.017	0.03	8.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Honey Creek	Mn-9	0745	--	--	65.0	6.4	7.8	340	144	853	0.66	0.11	0.023	0.34	1.134	0.023	0.06	2.9	1.3[d]	0.1[d]	1.4[d]	--	--	--	--	--	--	--	--	--	--	--	--
		1345	--	--	70.5	9.4	8.0	--	151	875	0.74	0.11	0.011	0.32	1.184	0.033	0.06	3.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1447	3.18	2.05	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.13	--	--	--	--	--	--	--	--	--	--	--
		1945	--	--	74.5	6.5	8.2	280	107	680	0.72	0.09	0.026	0.28	1.119	0.340	0.34	2.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		0130	--	--	69.0	5.5	7.9	--	95	1,022	0.63	0.09	0.157	0.73	1.613	0.433	0.41	4.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mn-13	0615	--	--	65.0	5.0	7.8	410	168	1,023	0.85	0.27	<0.002	0.15	1.270	0.005	0.04	2.8	--	--	4.3		--	--	--	--	--	--	--	--	--	--	--
		1215	--	--	80.0	18.4	8.6	--	187	993	0.86	0.14	0.007	0.09	1.096	0.009	0.05	4.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
		1815	--	--	77.5	12.3	8.8	320	158	780	0.91	0.09	<0.002	0.08	1.085	0.012	0.04	4.8	--	--	8.0	--	--	--	--	--	--	--	--	--	--	--	--
		0015	--	--	70.0	3.7	7.6	--	124	796	0.79	0.27	<0.002	0.05	1.120	0.010	0.05	17.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

[a] Values are in mg/l except as indicated.

[b] Values are in MFFCC/100 ml.

[c] Values are in micro mhos/cm at 77°F.

[d] Composite sample made up from the first and third sample periods.

Source: Wisconsin Department of Natural Resources, U. S. Geological Survey, and SEWRPC.

Appendix F

RESULTS OF FISH SHOCKING SURVEYS IN THE MENOMONEE RIVER WATERSHED BY STATION—AUGUST AND SEPTEMBER 1973

Stream Stations

Species and Population per Species According to Their Relative Tolerance to Organic Pollution

Station Number	Stream	Ecologic Unit	Very Tolerant: Central Mudminnow Umbra limi	Very Tolerant: Goldfish Carassius auratus	Very Tolerant: Carp Cyprinus carpio	Very Tolerant: Black Bullhead Ictalurus melas	Very Tolerant: White Sucker Catostomus commersonni	Very Tolerant: Fathead Minnow Pimephales promelas	Very Tolerant: Species	Very Tolerant: Population Number	Very Tolerant: Population Percent of Station Total	Tolerant: Bluntnose Minnow Pimephales notatus	Tolerant: Green Sunfish Lepomis cyanellus	Tolerant: Pumpkinseed Lepomis gibbosus	Tolerant: Creek Chub Semotilus atromaculatus	Tolerant: Bluegill Lepomis macrochirus	Tolerant: Large Mouth Bass Micropterus salmoides	Tolerant: Yellow Perch Perca flavescens	Tolerant: Brook Stickleback Culaea inconstans	Tolerant: Golden Shiner Notemigonus chrysoleucas	Tolerant: Common Shiner Notropis cornutus	Tolerant: Species	Tolerant: Population Number	Tolerant: Population Percent of Station Total	Intolerant: Johnny Darter Etheostoma nigrum	Intolerant: Brassy Minnow Hybognathus hankinsoni	Intolerant: Pearl Dace Semotilus margarita	Intolerant: Stone Roller Campostoma anomalum	Intolerant: Black Nosed Dace Rhinichthys atratulus	Intolerant: Southern Red Belly Dace Chrosomus erythrogaster	Intolerant: Northern Red Belly Dace Chrosomus eos	Intolerant: Fantail Darter Etheostoma flabellare	Intolerant: Species	Intolerant: Population Number	Intolerant: Population Percent of Station Total	Total Number of Species	Total Population
1	Upper Menomonee River	I	716	0	0	0	90	19	3	825	83.3	4	10	0	0	0	1	0	127	0	0	4	142	14.30	1	0	23	0	0	0	0	0	2	24	2.40	9	991
2	Upper Menomonee River	I	91	0	0	320	29	1	4	441	72.4	0	105	1	53	0	5	0	0	1	0	5	165	27.10	0	0	0	3	0	0	0	0	1	3	0.50	10	609
3	Upper Menomonee River	I	496	0	0	36	30	67	4	629	84.0	36	37	0	3	0	2	0	37	1	0	6	116	15.50	3	3	0	0	0	0	0	0	2	6	0.80	12	751
4	Upper Menomonee River	II	12	0	0	0	0	13	2	25	14.8	4	0	0	6	0	0	0	0	0	1	3	11	6.50	0	0	1	8	123	0	0	0	3	132	78.70	8	168
5	Upper Menomonee River	II	163	0	0	0	63	32	3	258	80.4	0	8	1	29	0	0	0	9	0	16	5	63	19.60	0	0	0	0	0	0	0	0	0	0	0.00	8	321
6	Upper Menomonee River	II	22	2	9	0	3	33	5	69	47.6	2	10	2	11	0	0	0	0	0	49	5	74	51.00	0	0	0	0	2	0	0	0	1	2	1.40	11	145
7	Upper Menomonee River	II	0	0	0	0	0	4	1	4	13.3	1	1	0	5	0	0	0	3	0	3	5	13	43.30	0	0	0	0	13	0	0	0	1	13	43.30	7	30
8	Lower Menomonee River	III	0	2	0	0	0	0	1	2	14.3	0	3	0	8	0	0	0	0	0	0	2	11	78.60	0	0	0	0	1	0	0	0	1	1	7.10	4	14
9	Lower Menomonee River	III	0	0	0	0	4	9	2	13	50.0	0	3	0	5	0	0	0	4	0	0	3	12	46.20	0	0	0	0	1	0	0	0	1	1	3.90	6	26
10	Lower Menomonee River	III	2	1	0	0	0	3	3	6	31.6	0	1	0	0	0	0	0	6	0	0	2	7	36.80	0	0	0	0	6	0	0	0	1	6	31.60	6	19
11	Lower Menomonee River	III	0	1	0	0	0	0	1	1	100.0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0.00	1	1
12	West Branch of the Menomonee River	I	38	0	0	0	10	24	3	72	37.9	0	22	0	5	0	0	0	33	0	0	3	60	31.60	1	0	24	0	21	0	12	0	4	58	30.50	10	190
13	Willow Creek	I	10	0	0	0	13	1	3	24	9.6	3	6	0	35	0	0	0	20	0	0	4	64	25.50	33	0	25	49	54	0	0	2	5	163	64.90	12	251
14	Little Menomonee River	V	0	0	0	0	8	4	2	12	10.2	43	2	0	12	0	0	0	44	0	0	4	101	85.60	0	0	0	0	5	0	0	0	1	5	4.20	7	118
15	Little Menomonee River	V	0	0	0	3	3	0	2	6	100.0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0.00	2	6
16	Little Menomonee River	VI	2	0	0	0	0	1	2	3	18.8	1	0	0	0	0	0	0	12	0	0	2	13	81.30	0	0	0	0	0	0	0	0	0	0	0.00	4	16
17	Little Menomonee Creek	V	1	0	0	0	2	1	3	4	20.0	0	8	0	0	0	0	0	6	0	0	2	14	70.00	2	0	0	0	0	0	0	0	1	2	10.00	6	20
18	Little Menomonee Creek	V	0	0	0	0	0	0	0	0	0.0	0	0	0	3	0	0	0	0	0	0	1	3	100.00	0	0	0	0	0	0	0	0	0	0	0.00	1	3
19	Noyes Creek	VI	0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0.00	0	0
20	Underwood Creek	VII	0	0	0	0	0	0	0	0	0.0	0	0	0	100	0	0	0	0	0	7	2	107	81.70	0	0	0	0	20	4	0	0	2	24	18.30	4	131
21	South Branch of the Underwood Creek	VII	3	16	0	0	0	5	3	24	30.4	0	41	2	7	9	1	0	0	0	0	5	55	69.60	0	0	0	0	0	0	0	0	0	0	0.00	8	79
22	Honey Creek	VIII	0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0.00	0	0
23	Honey Creek	VIII	0	0	0	0	0	0	1	3	30.0	0	7	0	0	0	0	0	0	0	0	1	7	0.51	0	0	0	0	0	0	0	0	0	0	0.00	2	10
24	Woods Creek	IV	0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0.00	0	0
Stream Station Totals			1,556	25	9	359	255	217	6.	2,421	62.1	94	264	6	277	9	9	0	301	2	76	9	1,038	26.60	40	3	73	60	246	4	12	2	8	440	11.30	123	3,899

Pond Stations

Species and Population per Species According to Their Relative Tolerance to Organic Pollution

Station Number	Stream	Ecologic Unit	Very Tolerant: Central Mudminnow Umbra limi	Very Tolerant: Goldfish Carassius auratus	Very Tolerant: Carp Cyprinus carpio	Very Tolerant: Black Bullhead Ictalurus melas	Very Tolerant: White Sucker Catostomus commersonni	Very Tolerant: Fathead Minnow Pimephales promelas	Very Tolerant: Species	Very Tolerant: Population Number	Very Tolerant: Population Percent of Station Total	Tolerant: Bluntnose Minnow Pimephales notatus	Tolerant: Green Sunfish Lepomis cyanellus	Tolerant: Pumpkinseed Lepomis gibbosus	Tolerant: Creek Chub Semotilus atromaculatus	Tolerant: Bluegill Lepomis macrochirus	Tolerant: Large Mouth Bass Micropterus salmoides	Tolerant: Yellow Perch Perca flavescens	Tolerant: Brook Stickleback Culaea inconstans	Tolerant: Golden Shiner Notemigonus chrysoleucas	Tolerant: Common Shiner Notropis cornutus	Tolerant: Species	Tolerant: Population Number	Tolerant: Population Percent of Station Total	Intolerant: Johnny Darter Etheostoma nigrum	Intolerant: Brassy Minnow Hybognathus hankinsoni	Intolerant: Pearl Dace Semotilus margarita	Intolerant: Stone Roller Campostoma anomalum	Intolerant: Black Nosed Dace Rhinichthys atratulus	Intolerant: Southern Red Belly Dace Chrosomus erythrogaster	Intolerant: Northern Red Belly Dace Chrosomus eos	Intolerant: Fantail Darter Etheostoma flabellare	Intolerant: Species	Intolerant: Population Number	Intolerant: Population Percent of Station Total	Total Number of Species	Total Population
25	Menomonee Park Pond	III	0	1	1	0	0	0	2	2	100.00	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0.00	2	2
26	Jacobus Park Pond	III	0	4	1	3	0	0	3	8	2.50	0	287	20	0	9	1	0	0	0	0	4	317	97.50	0	0	0	0	0	0	0	0	0	0	0.00	7	325
27	McCarty Park Pond	VIII	0	0	0	0	0	0	0	0	0.00	0	18	154	0	12	0	16	0	0	0	4	200	100.00	0	0	0	0	0	0	0	0	0	0	0.00	4	200
28	Woods Pond	IV	0	273	1	1	0	0	3	275	100.00	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0.00	3	275
Pond Station Totals			0	278	3	4	0	0	3	285	35.50	0	305	174	0	21	1	16	0	0	0	5	517	64.50	0	0	0	0	0	0	0	0	0	0	0.00	8	802

Source: Wisconsin Department of Natural Resources and SEWRPC.

Appendix G

SYSTEMATIC RESUME OF WILDLIFE LIKELY TO EXIST IN THE MENOMONEE RIVER WATERSHED

Phylum	Class	Order	Family	Genus	Species	Common Name
Chordata	Osteichthyes	Eventognathi	Umbridae	Umbra	limi	Central mudminnow
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Cyprinus	carpio	Carp
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Carassius	auratus	Goldfish
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Campostoma	anomalum	Stone roller
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Rhinichthys	atratulus	Black nosed dace
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Semotilus	afromaculatus	Creek chub
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Semotilus	margarita	Pearl dace
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Chrosomus	erythrogaster	Southern redbelly dace
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Chrosomus	eos	Northern redbelly dace
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Notemigonus	crysoleucas	Golden shiner
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Pimephales	notatus	Blunt nose minnow
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Pimephales	promelas	Fathead minnow
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Notropis	cornutus	Common shiner
Chordata	Osteichthyes	Eventognathi	Cyprinidae	Hybognathus	hankinsoni	Brassy minnow
Chordata	Osteichthyes	Ostariophysi	Catostomidae	Catostomus	commersoni	White sucker
Chordata	Osteichthyes	Ostariophysi	Ictaluridae	Ictalurus	melas	Black bullhead
Chordata	Osteichthyes	Thoracosteri	Gasterosteidae	Culaea	inconstans	Brook stickleback
Chordata	Osteichthyes	Acanthopteri	Centrarchidae	Micropterus	salmoides	Large mouth bass
Chordata	Osteichthyes	Acanthopteri	Centrarchidae	Lepomis	cyanellus	Green sunfish
Chordata	Osteichthyes	Acanthopteri	Centrarchidae	Lepomis	macrochirus	Bluegill
Chordata	Osteichthyes	Acanthopteri	Centrarchidae	Lepomis	gibbosus	Pumpkinseed
Chordata	Osteichthyes	Acanthopteri	Percidae	Perca	flavescens	Yellow perch
Chordata	Osteichthyes	Acanthopteri	Percidae	Etheostoma	nigrum	Johnny darter
Chordata	Osteichthyes	Acanthopteri	Percidae	Etheostoma	flabellare	Fantail darter
Chordata	Amphibia	Urodela	Proteidae	Necturus	maculosus	Mudpuppy
Chordata	Amphibia	Urodela	Ambystomidae	Ambystoma	luterale	Blue spotted salamander
Chordata	Amphibia	Urodela	Ambystomidae	Ambystoma	maculatum	Spotted salamander
Chordata	Amphibia	Urodela	Ambystomidae	Ambystoma	tigrium	Tiger salamander
Chordata	Amphibia	Urodela	Salamandridae	Notophthalamus	viridescens	Eastern newt
Chordata	Amphibia	Urodela	Plethodontidae	Plethodon	cinereus	Red backed salamander
Chordata	Amphibia	Anura	Ranidae	Rana	catesbeianna	Bullfrog
Chordata	Amphibia	Anura	Ranidae	Rana	climitans	Green frog
Chordata	Amphibia	Anura	Ranidae	Rana	pipiens	Leopard frog
Chordata	Amphibia	Anura	Ranidae	Rana	palustris	Pickerel frog
Chordata	Amphibia	Anura	Ranidae	Rana	sylvatica	Wood frog
Chordata	Amphibia	Anura	Bufonidae	Bufo	americanus	American toad
Chordata	Amphibia	Anura	Hylidae	Acris	crepitans	Cricket frog
Chordata	Amphibia	Anura	Hylidae	Hyla	crusifer	Spring peeper
Chordata	Amphibia	Anura	Hylidae	Hyla	versicolor	Gray treefrog
Chordata	Amphibia	Anura	Hylidae	Pseudaris	triseriata triseriata	Chorus frog
Chordata	Reptilia	Chelonia	Chelydridae	Chelydra	serpentina	Snapping turtle
Chordata	Reptilia	Chelonia	Chelydridae	Stenothaerus	odoratus	Musk turtle
Chordata	Reptilia	Chelonia	Testudinidae	Graptemys	geographica	True map turtle
Chordata	Reptilia	Chelonia	Testudinidae	Chrysemys	picta marginata	Midland painted turtle
Chordata	Reptilia	Chelonia	Testudinidae	Emydoidea	blandingi	Blandings turtle
Chordata	Reptilia	Chelonia	Trionychidae	Trionyx	spinifer spinifer	Eastern spiny softshell turtle
Chordata	Reptilia	Squamata	Scincidae	Eumeces	fasciatus	Five lined skink
Chordata	Reptilia	Squamata	Colubridae	Natrix	sipedon	Northern water snake
Chordata	Reptilia	Squamata	Colubridae	Regina (Natrix)	septemvittata	Queen snake
Chordata	Reptilia	Squamata	Colubridae	Storeria	dekayi dekayi	Northern brown snake
Chordata	Reptilia	Squamata	Colubridae	Storeria	occipitomaculata	Red bellied snake
Chordata	Reptilia	Squamata	Colubridae	Thamnophis	sirtalis sirtalis	Eastern garter snake
Chordata	Reptilia	Squamata	Colubridae	Thamnophis	radix	Prairie garter snake

Phylum	Class	Order	Family	Genus	Species	Common Name
Chordata	Reptilia	Squamata	Colubridae	Thamnophis	butleri	Butler's garter snake
Chordata	Reptilia	Squamata	Colubridae	Heterodon	platyrhinos	Hog nosed snake
Chordata	Reptilia	Squamata	Colubridae	Diadophis	punctatus edwardsi	Eastern (northern) ring necked snake
Chordata	Reptilia	Squamata	Colubridae	Pituophis	melanoleucus sayi	Bull snake
Chordata	Reptilia	Squamata	Colubridae	Lampropeltis	triangulum triangulum	Eastern milk snake
Chordata	Aves	Podicipediformes	Podicipedidae	colymbus	auritus	Horned greebe
Chordata	Aves	Podicipediformes	Podicipedidae	Podilymbus	podiceps podiceps	Pied billed greebe
Chordata	Aves	Pelecaniformes	Phalacrocoracidae	Phalacrocorax	auritus	Double crested cormorant
Chordata	Aves	Ardeiformes	Ardeidae	Ardea	herodias	Great blue heron
Chordata	Aves	Ardeiformes	Ardeidae	Butorides	virescens virescens	Green heron
Chordata	Aves	Ardeiformes	Ardeidae	Nycticorax	nycticorax hoactli	Black crowned night heron
Chordata	Aves	Ardeiformes	Ardeidae	Ixobrychus	exilis exilis	Least bittern
Chordata	Aves	Ardeiformes	Ardeidae	Botaurus	lentiginous	American bittern
Chordata	Aves	Anseriformes	Anatidae	Cygnus	columbianus	Whistling swan
Chordata	Aves	Anseriformes	Anatidae	Chen	hyperborea	Snow goose
Chordata	Aves	Anseriformes	Anatidae	Anas	platyrhynchos platyrhynchos	Mallard
Chordata	Aves	Anseriformes	Anatidae	Anas	rubripes	Black duck
Chordata	Aves	Anseriformes	Anatidae	Anas	strepera	Gadwall
Chordata	Aves	Anseriformes	Anatidae	Anas	acuta tzitzihoa	Pintail
Chordata	Aves	Anseriformes	Anatidae	Anas	carolinensis	Green-winged teal
Chordata	Aves	Anseriformes	Anatidae	Anas	discors	Blue-winged teal
Chordata	Aves	Anseriformes	Anatidae	Mareca	americana	American wigeon
Chordata	Aves	Anseriformes	Anatidae	Spatula	clypeata	Northern shoveler
Chordata	Aves	Anseriformes	Anatidae	Aix	sponsa	Wood duck
Chordata	Aves	Anseriformes	Anatidae	Aythya	americana	Redhead
Chordata	Aves	Anseriformes	Anatidae	Aythya	collaris	Ring-necked duck
Chordata	Aves	Anseriformes	Anatidae	Aythya	valisineria	Canvasback
Chordata	Aves	Anseriformes	Anatidae	Aythya	marila nearctica	Greater scaup
Chordata	Aves	Anseriformes	Anatidae	Aythya	affinis	Lesser scaup
Chordata	Aves	Anseriformes	Anatidae	Glaucionetta	clangula americana	Common goldeneye
Chordata	Aves	Anseriformes	Anatidae	Glaucionetta	albeola	Bufflehead
Chordata	Aves	Anseriformes	Anatidae	Erismatura	jamaicensis rubida	Ruddy duck
Chordata	Aves	Anseriformes	Anatidae	Lophodytes	cucullatus	Hooded merganser
Chordata	Aves	Anseriformes	Anatidae	Mergus	merganser americanus	Common merganser
Chordata	Aves	Anseriformes	Anatidae	Mergus	serrator	Red-breasted merganser
Chordata	Aves	Accipitriformes	Vulturidae	Cathartes	aura	Turkey vulture
Chordata	Aves	Accipitriformes	Accipitridae	Accipiter	strintus velox	Sharp-shinned hawk
Chordata	Aves	Accipitriformes	Accipitridae	Accipiter	gentilis atricapillus	Goshawk
Chordata	Aves	Accipitriformes	Accipitridae	Accipiter	cooperii	Cooper's hawk
Chordata	Aves	Accipitriformes	Accipitridae	Buteo	jamaicensis	Red-tailed hawk
Chordata	Aves	Accipitriformes	Accipitridae	Buteo	lineatus	Red-shouldered hawk
Chordata	Aves	Accipitriformes	Accipitridae	Buteo	platypterus platypterus	Broad winged hawk
Chordata	Aves	Accipitriformes	Accipitridae	Buteo	lagopus johannis	Rough-legged hawk
Chordata	Aves	Accipitriformes	Accipitridae	Halioctus	leucocephalus	Bald eagle
Chordata	Aves	Accipitriformes	Accipitridae	Circus	cyancos hudsonius	Mark hawk
Chordata	Aves	Accipitriformes	Pandionidae	Pandion	halivetus carolinensis	Osprey

Phylum	Class	Order	Family	Genus	Species	Common Name
Chordata	Aves	Accipitriformes	Falconidae	Falco	columbarius	Merlin
Chordata	Aves	Galliformes	Tetronidae	Bonasa	umbellus	Ruffed grouse
Chordata	Aves	Galliformes	Phasianidae	Colinus	virginianus	Bobwhite
Chordata	Aves	Galliformes	Phasianidae	Phasianus	colchicus torquatus	Ring-necked pheasant (introduced)
Chordata	Aves	Galliformes	Phasianidae	Perdix	perdix	Gray partridge (introduced)
Chordata	Aves	Gruiformes	Gruidae	Grus	canadensis	Sandhill crane
Chordata	Aves	Gruiformes	Rallidae	Rallus	elegans elegans	King rail
Chordata	Aves	Gruiformes	Rallidae	Rallus	limicola limicola	Virginia rail
Chordata	Aves	Gruiformes	Rallidae	Porzana	carolina	Sora rail
Chordata	Aves	Gruiformes	Rallidae	Gallinula	chloropus cachinnans	Common gallinule
Chordata	Aves	Gruiformes	Rallidae	Fulica	americana	American coot
Chordata	Aves	Charadriiformes	Charadriidae	Charadrius	hiaticula semipalmatus	Semipalmated plover
Chordata	Aves	Charadriiformes	Charadriidae	Charadrius	vociferus vociferus	Killdeer
Chordata	Aves	Charadriiformes	Charadriidae	Pluviulis	dominica dominica	American golden plover
Chordata	Aves	Charadriiformes	Charadriidae	Squatarola	squatarola	Black-bellied plover
Chordata	Aves	Charadriiformes	Charadriidae	Arenuria	interpres morinella	Raddy turnstone
Chordata	Aves	Charadriiformes	Scolopacidae	Philohela	minor	Woodcock
Chordata	Aves	Charadriiformes	Scolopacidae	Capella	gallinago	Common snipe
Chordata	Aves	Charadriiformes	Scolopacidae	Bartramia	longlcauda	Upland sandpiper
Chordata	Aves	Charadriiformes	Scolopacidae	Actitis	macularia	Spotted sandpiper
Chordata	Aves	Charadriiformes	Scolopacidae	Tringa	solitaria solitaria	Solitary sandpiper
Chordata	Aves	Charadriiformes	Scolopacidae	Totanus	melanoleucus	Greater yellow legs
Chordata	Aves	Charadriiformes	Scolopacidae	Totanus	flavipes	Lesser yellow legs
Chordata	Aves	Charadriiformes	Scolopacidae	Erolia	melanotos	Pectoral sandpiper
Chordata	Aves	Charadriiformes	Scolopacidae	Erolia	fuscicollis	White rumped sandpiper
Chordata	Aves	Charadriiformes	Scolopacidae	Erolia	bairdii	Baird's sandpiper
Chordata	Aves	Charadriiformes	Scolopacidae	Erolia	minutilla	Least sandpiper
Chordata	Aves	Charadriiformes	Scolopacidae	Erolia	alpina pacifica	Dunlin Short bill dowitcher
Chordata	Aves	Charadriiformes	Scolopacidae	Linnodrumus	griscus scolopaceus	Long bill dowitcher
Chordata	Aves	Charadriiformes	Scolopacidae	Micropalana	himantopus	Stilt sandpiper
Chordata	Aves	Charadriiformes	Scolopacidae	Ereunetes	pusillus	Seimi pallmated Sandpiper
Chordata	Aves	Charadriiformes	Scolopacidae	Crocethia	alba	Sanderling
Chordata	Aves	Charadriiformes	Pharlaropodidae	Steganopus	tricolor	Willson's phalarope
Chordata	Aves	Charadriiformes	Pharlaropodidae	Lobipes	lobatus	Northern phalarope
Chordata	Aves	Charadriiformes	Laridae	Larus	argentatus	Herring gull
Chordata	Aves	Charadriiformes	Laridae	Larus	delawarensis	Ring billed gull
Chordata	Aves	Charadriiformes	Laridae	Larus	pipixcan	Franklin's gull
Chordata	Aves	Charadriiformes	Laridae	Larus	philidelphia	Bonaparte's gull
Chordata	Aves	Charadriiformes	Laridae	Sterna	forsteri	Forster's tern
Chordata	Aves	Charadriiformes	Laridae	Sterna	hirundo hirundo	Common tern
Chordata	Aves	Charadriiformes	Laridae	Hydroprogne	caspia	Caspian tern
Chordata	Aves	Charadriiformes	Laridae	Chlidonias	nigra surinamensis	Black tern
Chordata	Aves	Coluinbiformes	Columbidae	Coluvmba	livia	Rock dove
Chordata	Aves	Coluinbiformes	Columbidae	Zenaidura	macroura	Mourning dove
Chordata	Aves	Cuculiformes	Cuculidae	Coccyzus	americanus americanus	Yellow billed cuckoo
Chordata	Aves	Cuculiformes	Cuculidae	Coccyzus	erythrophthalmus	Black billed cuckoo
Chordata	Aves	Stigiformes	Tytonidae	Tyto	alba pratincola	Barn owl
Chordata	Aves	Stigiformes	Strigidae	Otus	asio	Screech owl
Chordata	Aves	Stigiformes	Strigidae	Bubu	virginianus	Great horned owl

Phylum	Class	Order	Family	Genus	Species	Common Name
Chordata	Aves	Stigiformes	Strigidae	Nyctea	scandiacra	Snowy owl
Chordata	Aves	Stigiformes	Strigidae	Asio	otus wilsonianus	Long eared owl
Chordata	Aves	Stigiformes	Strigidae	Asio	flammeus flammeus	Short eared owl
Chordata	Aves	Stigiformes	Strigidae	Aegolius	acadica acadica	Saw-whet owl
Chordata	Aves	Caprimugiformes	Oaprimulgidae	Cuprimulqus	vociferus	Whip-poor-will
Chordata	Aves	Caprimugiformes	Oaprimulgidae	Cherdeiles	minor	Night hawk
Chordata	Aves	Apodiformes	Apodidae	Choetura	pelagica	Chimney swift
Chordata	Aves	Coraciiformes	Apodidae	Megaceryle	alcyon alcyon	Betted king fisher
Chordata	Aves	Piciformes	Picidae	Colaptes	duratus	Flicker
Chordata	Aves	Piciformes	Picidae	Hylatomus	pileatus	Pileated woodpecker
Chordata	Aves	Piciformes	Picidae	Centurus	carolinus	Red-bellied woodpecker
Chordata	Aves	Piciformes	Picidae	Melanerpes	erythrocephalus erythrocephalus	Red headed woodpecker
Chordata	Aves	Piciformes	Picidae	Sphyrapicus	varius varius	Yellow-bellied sapsucker
Chordata	Aves	Piciformes	Picidae	Dendrocopus	villosus	Hairy woodpecker
Chordata	Aves	Piciformes	Picidae	Dendrocopus	pubescens	Downy woodpecker
Chordata	Aves	Trochiliformes	Trochilidae	Archilochus	colubris	Ruby-throated hummingbird
Chordata	Aves	Passeriformes	Tyrannidae	Tyrannus	tyrannus	Eastern kingbird
Chordata	Aves	Passeriformes	Tyrannidae	Mycarchus	crinitus	Great crested flycatcher
Chordata	Aves	Passeriformes	Tyrannidae	Sayornis	phoebe	Phoebe, eastern
Chordata	Aves	Passeriformes	Tyrannidae	Empidonox	flaviventris	Yellow-bellied flycatcher
Chordata	Aves	Passeriformes	Tyrannidae	Empidonox	virescens	Acadian flycatcher
Chordata	Aves	Passeriformes	Tyrannidae	Empidonox	traillii traillii	Traill's flycatcher (alder)
Chordata	Aves	Passeriformes	Tyrannidae	Contopus	virens	Wood pewee
Chordata	Aves	Passeriformes	Tyrannidae	Nuttallornis	borealis	Olive sided flycatcher
Chordata	Aves	Passeriformes	Tyrannidae	Eremophila	alpestris	Horned lark
Chordata	Aves	Passeriformes	Hirundinidae	Iridoprocne	bicolor	Tree swallow
Chordata	Aves	Passeriformes	Hirundinidae	Riparia	riparia riparia	Bank swallow
Chordata	Aves	Passeriformes	Hirundinidae	Stelgidopteryx	ruficollis serripennis	Rough winged swallow
Chordata	Aves	Passeriformes	Hirundinidae	Hirundo	rustica erythrogaster	Barn swallow
Chordata	Aves	Passeriformes	Hirundinidae	Petrochelidon	pyrrhonota albifrons	Cliff swallow
Chordata	Aves	Passeriformes	Hirundinidae	Progne	subis subis	Purple martin
Chordata	Aves	Passeriformes	Coruidae	Cyanocitta	cristaica	Blue jay
Chordata	Aves	Passeriformes	Coruidae	Corous	brachyrhynchos	Crow
Chordata	Aves	Passeriformes	Puridae	Parus	atricapillus	Black-capped chickadee
Chordata	Aves	Passeriformes	Puridae	Parus	bicolor	Tufted titmouse
Chordata	Aves	Passeriformes	Sihrdae	Sitta	carolinensis	White breasted nuthatch
Chordata	Aves	Passeriformes	Sihrdae	Sitta	canadensis	Red breasted nuthatch
Chordata	Aves	Passeriformes	Certhiidae	Certhia	familiaris	Brown creeper
Chordata	Aves	Passeriformes	Troglodytidae	Troglodytes	aedon	House wren
Chordata	Aves	Passeriformes	Troglodytidae	Troglodytes	troglodytes	Winter wren
Chordata	Aves	Passeriformes	Troglodytidae	Thryomanes	bewickii	Bewick's wren
Chordata	Aves	Passeriformes	Troglodytidae	Telmatodytes	palustris	Long-billed marsh wren
Chordata	Aves	Passeriformes	Troglodytidae	Cistothorus	platensis stellaris	Short-billed marsh wren
Chordata	Aves	Passeriformes	Mimidae	Dumetella	carolinensis	Grey catbird
Chordata	Aves	Passeriformes	Mimidae	Toxostoma	rufum rufum	Brown thrasher
Chordata	Aves	Passeriformes	Turidae	Turdus	migratorious	American robin
Chordata	Aves	Passeriformes	Turidae	Hylocichla	mustelina	Wood thrush
Chordata	Aves	Passeriformes	Turidae	Hylocichla	guttata faxoni	Hermit thrush
Chordata	Aves	Passeriformes	Turidae	Hylocichla	ustalata swainsoni	Swainson's thrush
Chordata	Aves	Passeriformes	Turidae	Hylocichla	minima	Gray cheeked thrush
Chordata	Aves	Passeriformes	Turidae	Hylocichla	fuscescens	Veery
Chordata	Aves	Passeriformes	Turidae	Sialia	sialis	Eastern bluebird
Chordata	Aves	Passeriformes	Sylvidae	Polioptila	coerulea coerulea	Blue-gray gnatcatcher

Phylum	Class	Order	Family	Genus	Species	Common Name
Chordata	Aves	Passeriformes	Sylvidae	Regulus	satrapa satrapa	Golden crowned kinglet
Chordata	Aves	Passeriformes	Motacillidae	Anthus	spinoletta rubescens	Water-pipit
Chordata	Aves	Passeriformes	Bonbycillidae	Bombycilla	aarrulus pallidiceps	Boheman waxwing
Chordata	Aves	Passeriformes	Bonbycillidae	Bombycilla	cedrorum	Cedar waxwing
Chordata	Aves	Passeriformes	Sturnidae	Sturnus	vulgaris vulgaris	Starling (introduced)
Chordata	Aves	Passeriformes	Vireonidae	Vireo	flavifrons	Yellow throated vireo
Chordata	Aves	Passeriformes	Vireonidae	Vireo	solitarius	Solitary vireo
Chordata	Aves	Passeriformes	Vireonidae	Vireo	olivaceus	Red eyed vireo
Chordata	Aves	Passeriformes	Vireonidae	Vireo	philidelphicus	Philidelphia vireo
Chordata	Aves	Passeriformes	Vireonidae	Vireo	gilvus gilvus	Warbling vireo
Chordata	Aves	Passeriformes	Parulidae	Mniotilta	varia	Black and white warbler
Chordata	Aves	Passeriformes	Parulidae	Protonotaria	citrea	Prothonotary warbler
Chordata	Aves	Passeriformes	Parulidae	Vermivora	chrysopteva	Golden winged warbler
Chordata	Aves	Passeriformes	Parulidae	Vermivora	pinus	Blue winged warbler
Chordata	Aves	Passeriformes	Parulidae	Vermivora	peregrina	Tennessee warbler
Chordata	Aves	Passeriformes	Parulidae	Vermivora	ruficapilla ruficapilla	Nashville warbler
Chordata	Aves	Passeriformes	Parulidae	Parula	americana pusilla	Northern parula warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	petechia	Yellow warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	magnolia	Magnolia warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	tigrina	Cape may warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	coerulescens	Black throated blue warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	coronata coronata	Yellow rumped warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	virens	Black throated green warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	cerulea	Cerulean warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	fusca	Blackburnian warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	pensylvanica	Chestnut-sided warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	castanea	Bay breasted warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	striata	Blackpoll warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	pinus	Pine warbler
Chordata	Aves	Passeriformes	Parulidae	Dendroica	palmarum	Palm warbler
Chordata	Aves	Passeriformes	Parulidae	Seiurus	aurocapillus	Oven bird
Chordata	Aves	Passeriformes	Parulidae	Oporornis	agilis	Connecticut warbler
Chordata	Aves	Passeriformes	Parulidae	Oporornis	philadelphia	Mourning warbler
Chordata	Aves	Passeriformes	Parulidae	Geothlypis	trichas	Common yellow throat
Chordata	Aves	Passeriformes	Parulidae	Wilsonia	pusilla pusilla	Wilson's warbler
Chordata	Aves	Passeriformes	Parulidae	Wilsonia	canadensis	Canada warbler
Chordata	Aves	Passeriformes	Parulidae	Setophaga	ruticilla	American redstart
Chordata	Aves	Passeriformes	Parulidae	Paser	domesticus domesticus	House sparrow (introduced)
Chordata	Aves	Passeriformes	Icteridae	Dolicnonyx	oryzivorus	Bobolink
Chordata	Aves	Passeriformes	Icteridae	Sturnella	magna magna	Eastern meadow lark
Chordata	Aves	Passeriformes	Icteridae	Sturnella	neglecta	Western meadow lark
Chordata	Aves	Passeriformes	Icteridae	Xanthocephatus	Xanthocephatus	Yellow headed blackbird
Chordata	Aves	Passeriformes	Icteridae	Acleius	phoeniceus	Redwing blackbird
Chordata	Aves	Passeriformes	Icteridae	Icteous	spurius	Orchard oriole Northern oriole
Chordata	Aves	Passeriformes	Icteridae	Euphagus	carolinus	Rusty blackbird
Chordata	Aves	Passeriformes	Icteridae	Euphagus	cyanocephalas	Brewer's blackbird
Chordata	Aves	Passeriformes	Icteridae	Quiscalus	quiscula	Common grackle
Chordata	Aves	Passeriformes	Icteridae	Molothrus	ater ater	Brown-headed cowbird
Chordata	Aves	Passeriformes	Thraupidae	Piranga	olivacea	Scarlet tanager
Chordata	Aves	Passeriformes	Fringillidae	Richmondena	cardimalis	Cardinal

Phylum	Class	Order	Family	Genus	Species	Common Name
Chordata	Aves	Passeriformes	Fringillidae	Pheucticus	ludovicianus	Rose-breasted grosbeak
Chordata	Aves	Passeriformes	Fringillidae	Passerina	cyanea	Indigo bunting
Chordata	Aves	Passeriformes	Fringillidae	Spiza	americana	Dickcissel
Chordata	Aves	Passeriformes	Fringillidae	Hesperiphona	vespertina	Evening grosbeak
Chordata	Aves	Passeriformes	Fringillidae	Carpodacus	purpureus purpureus	Purple finch
Chordata	Aves	Passeriformes	Fringillidae	Pinicola	enucleator leucura	Pine grosbeak
Chordata	Aves	Passeriformes	Fringillidae	Acanthis	flammea	Common redpoll
Chordata	Aves	Passeriformes	Fringillidae	Spinus	pinus pinus	Pine siskin
Chordata	Aves	Passeriformes	Fringillidae	Spinus	tristis tristis	American goldfinch
Chordata	Aves	Passeriformes	Fringillidae	Loxia	caruirostra	Red grossbill
Chordata	Aves	Passeriformes	Fringillidae	Loxia	leucoptera leucoptera	White-winged grossbill
Chordata	Aves	Passeriformes	Fringillidae	Pipilo	erythrophthalmus	Rufous sided towhee
Chordata	Aves	Passeriformes	Fringillidae	Passerculus	sandwichensis	Savannah sparrow
Chordata	Aves	Passeriformes	Fringillidae	Poecetes	gramineas gramineas	Vesper sparrow
Chordata	Aves	Passeriformes	Fringillidae	Chondestes	grammacus grammacus	Lark sparrow
Chordata	Aves	Passeriformes	Fringillidae	Junco	hyemalis	Dark-eyed junco
Chordata	Aves	Passeriformes	Fringillidae	Spizella	arborea arborea	Tree sparrow
Chordata	Aves	Passeriformes	Fringillidae	Spizella	passerina passerina	Chipping sparrow
Chordata	Aves	Passeriformes	Fringillidae	Zonotrichia	querula	Harris sparrow
Chordata	Aves	Passeriformes	Fringillidae	Zonotrichia	leucophrys	White-crowned sparrow
Chordata	Aves	Passeriformes	Fringillidae	Passerella	iliaca iliaca	Fox sparrow
Chordata	Aves	Passeriformes	Fringillidae	Melospiza	lincolnii lincolnii	Lincoln's sparrow
Chordata	Aves	Passeriformes	Fringillidae	Melospiza	georgiana	Swamp sparrow
Chordata	Aves	Passeriformes	Fringillidae	Melospiza	melodia	Song sparrow
Chordata	Aves	Passeriformes	Fringillidae	Calcarius	lapponicus lapponicus	Lapland longspur
Chordata	Aves	Passeriformes	Fringillidae	Plectrophenax	nivalis nivalis	Snow bunting
Chordata	Mammalia	Marsupialia	Didelphiidae	Didelphis	marsupialis	Opossum
Chordata	Mammalia	Insectivora	Soricidae	Sorex	cinereus	Cinerous shrew
Chordata	Mammalia	Insectivora	Soricidae	Sorex	fumeus	Smoky shrew
Chordata	Mammalia	Insectivora	Soricidae	Sorex	arcticus	Saddle-backed shrew
Chordata	Mammalia	Insectivora	Soricidae	Sorex	palustris	Water shrew
Chordata	Mammalia	Insectivora	Soricidae	Microsorex	hogi	Pygmy shrew
Chordata	Mammalia	Insectivora	Soricidae	Blarina	brevicauda	Mole shrew
Chordata	Mammalia	Insectivora	Talpidae	Condyura	cristata	Starnosed mole
Chordata	Mammalia	Insectivora	Talpidae	Scalopus	aquaticus	Eastern mole
Chordata	Mammalia	Chiroptera	Vespertilionidae	Myotis	lucifugus	Little brown myotis
Chordata	Mammalia	Chiroptera	Vespertilionidae	Myotis	evotis	Long eared myotis
Chordata	Mammalia	Chiroptera	Vespertilionidae	Lasionycteris	noctivagans	Silver-haired bat
Chordata	Mammalia	Chiroptera	Vespertilionidae	Eptesicus	fuscus	Big brown bat
Chordata	Mammalia	Chiroptera	Vespertilionidae	Lasiurus	borealis	Red bat
Chordata	Mammalia	Chiroptera	Vespertilionidae	Lasiurus	cinereus	Hoary bat
Chordata	Mammalia	Lagomorpha	Leporidae	Sylvilagus	floridanus mearnsii	Mearn's cottontail
Chordata	Mammalia	Rodentia	Sciuridae	Marmota	monax	Wood chuck
Chordata	Mammalia	Rodentia	Sciuridae	Citellus	tridecemlineatus	Thirteen lined ground squirrel
Chordata	Mammalia	Rodentia	Sciuridae	Citellus	franklini	Franklin ground squirrel
Chordata	Mammalia	Rodentia	Sciuridae	Tamias	striatus griseus	Gray chipmunk
Chordata	Mammalia	Rodentia	Sciuridae	Tamias	striatus ohionensis	Ohio chipmunk
Chordata	Mammalia	Rodentia	Sciuridae	Sciurus	carolinensis	Tassel eared squirrel
Chordata	Mammalia	Rodentia	Sciuridae	Sciurus	niger	Eastern fox squirrel
Chordata	Mammalia	Rodentia	Sciuridae	Tamiasciurus	hudsonicus	Red squirrel

Phylum	Class	Order	Family	Genus	Species	Common Name
Chordata	Mammalia	Rodentia	Sciuridae	Glaucomys	volans	Southern Flying Squirrel
Chordata	Mammalia	Rodentia	Cricetidae	Glaucomys	volans	Prairie mouse
Chordata	Mammalia	Rodentia	Cricetidae	Peromyscus	leucopus	White footed mouse
Chordata	Mammalia	Rodentia	Cricetidae	Synaptomys	cooperi	Southern bog lemming
Chordata	Mammalia	Rodentia	Cricetidae	Zapus	hudsonius	Meadow jumping mouse
Chordata	Mammalia	Rodentia	Cricetidae	Clethrionomys	gapperi	Boreal redback vole
Chordata	Mammalia	Rodentia	Cricetidae	Microtus	pennsylvanicus	Meadow vole
Chordata	Mammalia	Rodentia	Cricetidae	Microtus	ochrogaster	Prairie vole
Chordata	Mammalia	Rodentia	Cricetidae	Microtus	pinetorum	Pine vole
Chordata	Mammalia	Rodentia	Cricetidae	Ondatra	zibethica	Muskrat
Chordata	Mammalia	Rodentia	Muridae	Rattus	norvegicus	Norway rat
Chordata	Mammalia	Rodentia	Muridae	Mus	musculus	House mouse
Chordata	Mammalia	Carnivora	Procyonidae	Procyon	lotor	Racoon
Chordata	Mammalia	Carnivora	Mustelidae	Mustela	ermina	Shortail weasel (ermine)
Chordata	Mammalia	Carnivora	Mustelidae	Mustela	rixosa	Least weasel
Chordata	Mammalia	Carnivora	Mustelidae	Mustela	frenata	Longtail weasel
Chordata	Mammalia	Carnivora	Mustelidae	Mustela	vison	Mink
Chordata	Mammalia	Carnivora	Mustelidae	Taxidea	taxus	Badger
Chordata	Mammalia	Carnivora	Mustelidae	Mephitis	mephitis	Striped skunk
Chordata	Mammalia	Carnivora	Canidae	Vulpes	fulva	Red fox
Chordata	Mammalia	Carnivora	Canidae	Urocyon	cinereoargenteus	Gray fox
Chordata	Mammalia	Artiodactyla	Cervidae	Odocoileus	virginianus	White tail deer

Source: Wisconsin Department of Natural Resources.

ERRATA SHEET

Chapter II

Page 20, right column, first full paragraph, line 9, should read: "hydrology, hydraulics, and water quality . . ."

Chapter III

Page 78, Map 22, caption, line 6, should read: ". . . covering only 3 percent . . ."
Page 81, left column, first full paragraph, line 1, should read: ". . . representing 24 different . . ."
Page 83, Map 23, caption, line 2, should read: ". . . and 24 different . . ."
Page 92, right column, third full paragraph, line 12, should read: "4.3 square miles or 3 percent . . ."
Page 93, right column, line 12, should read: "13 percent . . ."

Chapter VI

Page 214, figure 54, caption, line 3, should read: ". . . rapid rises in . . ."

Chapter VII

Page 260, right column, second paragraph, line 5, should read: ". . . 3.75 mile . . ."

Chapter VIII

Page 325, right column, line 12, should read: ". . . 11 hydrologic . . ."
Page 330, Table 71, heading of third column, should read: "Definition or Meaning"

Chapter IX

Page 374, right column, footnote 5, should read: ". . . *in Appendix F.*"
Page 395, left column, line 23, should read ". . . four are often considered game mammals while"

Chapter XI

Page 454, left column, line 7, should read: ". . . nearly 15.0 square miles or about 11 percent"

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